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Iron in Ancient India.

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THIS SERIES OF MONOGRAPHS

ON

THE KNOWLEDGE OF THE METALS IN ANCIENT INDIA

IS DEDICATED

TO

THE MEMORY OF THE LATE

DR. MAHENDRA LAL SIRCAR, M.D., D.L., C.I.E.,

THE FOUNDER OF THE

INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE,

AND THE

MOST ILLUSTRIOUS SCIENTIST OF INDIA

WHO WORKED STRENUOUSLY FOR SCIENCE AND MEDICINE

DURING THE LATTER HALF OF THE NINTEENTH

CENTURY, AS A RESPECTFUL TRIBUTE

OF GENUINE REGARD OF HIS

HUMBLE ADMIRER

THE AUTHOR.

INTRODUCTION.

My object in preparing this series of monographs is to study the knowledge of the ancient Hindus of the different metals and their compounds from ancient Sanskrit literature, medical and non-medical, and also from analytical, archæological and mineralogical sources. Dr. P. C. Ray, in his well-known "History of Hindu Chemistry," has collected a large amount of medical or rather medico-chemical Sanskrit literature bearing on the knowledge of the Hindus of the metals and their compounds, but I would like to submit that there are other sources, specially non-medical Sanskritic and archæological literature, which would throw considerable light on the subject. It is my desire to bring together in a connected form the information on all these heads as far as practicable so that a more detailed history of Hindu Chemistry may be written afterwards.

So far as the present monograph is concerned, it embodies in an enlarged form a lecture delivered on the 7th January, 1914, at the Indian Association for the Cultivation of Science, Dr. P. C. Ray presiding. I have attempted to discuss at considerable length the question whether iron was known in the Vedic Age, and I hope I have been able to prove that the use of iron was perfectly known to the first Aryan settlers in India. Such a discussion might throw some light on the vexed question of the prior use of iron and bronze, though so far as India is concerned there was no bronze age, as bronze weapons are scarcely to be found in India. As regards archæological evidence, ancient specimens of iron are so very abundant in India that an enumeration of these alone will convince any one that India has always been a rich iron-producing country. The great iron pillar at Delhi is well known to all, but I would like to draw prominent attention of all students of science to the other two less-known iron pillars, viz. the one at Dhar, which is nearly twice as big as the Delhi pillar, and the other on Mount Abu. Nor must we lose sight of the gigantic iron beams at Konarak, recently brought to full view from drift sea-sand in which many remained buried for two or three centuries, as well as of the numerous iron beams

at Puri and Bhubaneswar where as many as 239 pieces have been counted in the Puri Gunduchibāri temple alone.

I believe that the theory of forging small blooms of wrought iron into entire beams and pillars is the real solution of the question how these beams and pillars could have been forged with hand labour. As regards the solution of the problem how these pillars have so long withstood the rusting influence of wind and rain, my idea is that " low manganese with low sulphur and high phosphorus" in the composition of the iron has something to do with the " corrosion-resistance " capacity of wrought iron. I also suspect that the pillars and beams were originally painted.

As regards the metallurgy of iron, wrought iron was produced in India by the *direct process*, i.e. directly from the ores in small blast furnaces without the intermediate production of cast iron, whilst the modern process may be called the *indirect process*, in which wrought iron is prepared from cast iron which is first formed in modern blast furnaces.

I have devoted considerable space to the consideration of the manufacture of Indian steel which was certainly the material from which the famous Damascus blades were manufactured. It will be seen that the crucible process of making cast-steel by means of cementation was really an Indian invention, and that it was not till the nineteenth century that Mr. Mushet re-discovered the process in Europe.

In conclusion, I should take this opportunity of thanking Dr. Spooner, Superintendent of the Archæological Department, Indian Museum, Calcutta, for his permission to take photographs of the Budh-Gaya iron clamps, and Dr. J. H. Marshal, Director of the Archæological Department, Government of India, for his permission to reproduce the plates from the Reports of the Archæological Survey of India. I am also indebted to the publishers of the *Empress* for their loan of the blocks of the Bijapur Guns for use in this paper. Mahamahopadhyay Dr. Satish Chandra Vidyabhushan, Principal of the Sanskrit College, Calcutta, placed every facility at my disposal, enabling me to study Vedic literature on the subject in the library of the College. I should also state that I was not aware of Sir Robert Hadfield's excellent papers on "Singhalese Iron and Steel of ancient Origin"

in the Journal of the Iron and Steel Institute and Proceedings of the Royal Society, and that my attention was drawn to the papers at the meeting in which my paper was read. I have incorporated in this paper Sir Robert's analysis of Ceylon iron, as Ceylon was only a part of Greater India in ancient times.

P. NEOGI.

RAJSHAHI, 1914.

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Iron in Ancient India.

By P. Neogi.

CHAPTER I.

IRON IN THE VEDIC AGE[1] (CIRCA 2000—1000 B.C.).

The revival of iron industry in modern India under the auspices of the Bengal Iron and Steel and the Tata Iron and Steel Companies leads naturally to the question whether the present industry, which promises so much in the near future, is entirely a new venture in India or is a revival of past ventures in this direction. India is known to the West primarily as the abode of an ancient civilization rich in ethical and philosophical doctrines, but the fact that Indian civilization was rich in material progress also is slowly but steadily being brought to the notice of the world at large. So far as the present subject is concerned, a careful study of the available literature and archæological evidence will easily convince any student that India had always been in the past, as it promises to be in the near future, a rich iron-producing country. Well has Sir John Hickshaw said in his presidential address to the British Association Meeting at Bristol in 1875 that "the supply of iron in India, as early as the fourth and fifth centuries, seems to have been unlimited. India well repaid any advantages which she may have derived from the early civilized communities of the West if she were the first to supply them with iron and steel." Shaw

[1] Prof. Hermann Jacobi from astronomical calculations is inclined to push the beginning of the Vedic age so far back as 4000 B.C. We have, however, adopted here the more moderate estimate of the antiquity of the Vedic age. Prof. Max Müller is of opinion that the Vedas represent the most ancient writings in he world.

maintains that "the hardest tools in ancient Egypt, such as drills for working the granite obelisks, were made of Indian iron" and it was again from India, as will be shown later on, that the Persians and afterwards the Arabs and the Europeans learnt the tempering of steel, the best specimens of which were the famous Damascus blades of the Middle Ages. Roscoe and Schorlemmer in their well-known "Treatise on Chemistry" have written "it appears probable that iron was first obtained from its ores in India." They further say "the word iron, which is identical with the Scandinavian 'iarn' (instead of 'isarn') and German 'eisen' (adjective 'eisern') appears to be connected with the Sanskrit 'ayas' (Latin 'aes'), and this, according to Grimm, is an indication that bronze was in use amongst the Germans at a much earlier date than iron."

Ethnographists usually divide the age of using implements of warfare into principally three divisions, viz. stone age, bronze age and iron age. Such a division might be tenable in the case of European countries but hardly applicable in the case of India which was colonized by the Aryans possessing a very high order of civilization at a very early age. It is true that implements of the stone age are found scattered in Chota Nagpur, Central Provinces and other parts of India, but it seems that these stone implements were mostly used by the aboriginal, Palæolithic and Nœolithic, people who inhabited India before the Aryan Conquest and whose descendants are the Kols, Bhils and other aboriginal tribes of modern India. In India the use of bronze as material for making arms was never extensive, and weapons made of bronze are scarcely to be found, though Vincent Smith is disposed to maintain that there was a copper age in India prior to the iron age.[1] Vincent Smith, however, places the limit of the copper age at 1000 B.C., which falls easily in the Vedic age when, as will be shown later on, the use of iron was well known.

There is even a considerable difference of opinion about the general question whether bronze really preceded iron. The well-known metallurgist Dr. John Percy in his well-known treatise entitled "Metallurgy of Iron and Steel" held, and I think very

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[1] Vincent Smith, Indian Antiquary, 1905, Vol. xxxiv, p. 236.

rightly, that the use of bronze cannot really precede the use of iron. The preparation of bronze would presuppose the knowledge of the metallurgy at least of two metals, viz. copper and tin, whilst the use of iron requires the knowledge of the metallurgy of one metal only. Moreover, as Dr. Percy points out, the metallurgy of iron is very simple—"if a lump of red or brown hœmatite be heated for some time in a charcoal fire, well surrounded by or embedded in the fuel, it will be more or less completely reduced so as to admit of being easily forged at a red heat into a bar of iron." Mr. St. John V. Day, the author of "The Prehistoric use of Iron and Steel," also maintains that the use of iron preceded the so-called bronze age. At any rate so far as India is concerned there cannot be distinguished a distinct age called the bronze age, and the Aryan conquerors seem to have known the use of iron from their very first habitation in the Punjab, as can be gleaned from the frequent mention of iron in Vedic literature.

The word "Ayas" frequently occurs in the Rig and other Vedas. It means "iron" and has been translated as such by the great commentator Shāyana, Prof. Max Müller, Griffiths, Wilson, R. C. Dutt, the author of Bāchaspatya Lexicon, and others, though Shāyana in some passages has taken it to mean "gold" also. On the other hand Macdonell and Keith in their "Vedic Index" suppose it to mean "bronze," perhaps being influenced by the theory that bronze preceded iron in India also.[1] They argue "as favouring the sense of 'bronze' rather than that of 'iron' may perhaps be cited with Zimmer (Altindisches Leben, 52) the fact that Agni is called 'Ayo-daṃstra,' with the teeth of ayas, (Rig. I, 88, 5; X, 87, 2) with reference to the colour of his flames, and that the car-seat of Mitra and Varuna is called 'aya-sthuna' (Rig. V. 62, 8) with 'pillars of ayas' at the setting of the sun (but this is not convincing, as in the same verse it is said to be of 'golden appearance at the flash of dawn' (footnote)." I have been at some pains to consult the original text, specially Shāyana's commentary, and am afraid that Macdonell and Keith's argument cannot stand. As regards "ayo-daṃstra" in Rig. I,

[1] Vedic Index, pp. 31 and 32.

88, 5, it is an adjective of "barāhūn",[1] the passage being translated by Max Müller as "wild boars rushing about with iron tusks." I am completely at a loss how it may be taken to refer to the colour of flames. There are, however, other passages in which the word has been used as an adjective of Agni, for example in Rig. X, 87, 2, where Wilson translates it as "teeth of iron." The same passage occurs in Atharv. VIII, 3, 2, in which Whitney translates the word as "tusks of iron." The adjective evidently refers to the sharpness of the tongues of flames and not to their colour. Then as regards "ayo-sthuna" in Rig. V, 62, 8 (and also in Rig. V. 62, 7)[2] we find that Shāyana has rendered "ayas" as "gold." This rendering is in full agreement with what Macdonell and Keith mention "as golden appearance at the flash of dawn." In any case in this or similar passages we may safely take the rendering of the scholiast of "ayas" as "gold" as fully authoritative. There is absolutely no justification for bringing in the idea of "bronze"

But it is undoubted that 'ayas' in by far the largest number of passages in the Rigveda means "iron" and not "gold." In Rig. VI, 47, 10 and VI, 3, 5 occurs the passage 'ayasho na dhārām'[3] which is explained by Shāyana as 'shower of iron swords or javelins.' In Rig. VII, 95, 1[4] occurs the passage 'āyashī pūh' or 'iron city,' which, though not to be taken literally, means a safe place, and shows that the ancient Aryans were perfectly familiar with the strength and hardness of iron. The same words 'iron city' occur in another passage, Rig. VII, 15, 14.[5] The picture of 'iron melter or blacksmith melting iron in his forge' is given in Rig. IV, 2, 17 and Rig. VI, 3, 4.[6] We find in Rig. VI,

[1] The original passage is "अयो दंष्ट्रान् विधावतः वराहून्"।

[2] Shāyana comments thus: "स्थूणाः कीलकादयोऽयः हिरण्यनामैतत् अयोविकारा इत्यर्थः। अयोमयो वा। Mr. R. C. Dutt translates as "iron bolts" (लोहकीलक)।

[3] "अयसो न धारां"। In Rig. VI. 47, 10 Shāyana explains the passage as "अयोमयस्य वज्रादेर्धारामिव" and in Rig. VI. 3, 5, as "अयोमयस्य परश्वादेर्धाराम्"।

[4] Rig. VII, 95, 1, "आयसी पूः"

[5] Rig. VII, 15, 14, "अधा मही न आयस्यनाधृष्टो नृपीतये पूर्भवा शतभुजिः"।

[6] Rig. IV, 2, 17—"सुकर्माणः सुरुचो देवयन्तोऽयो न देवा जनिमा धमन्तः"। This passage is commented upon by Shāyana as follows: "यथा कर्मारा अयो भस्त्रेण

75, 15 that arrows were tipped with iron.[1] Hardness of iron is again referred to in Rig. I, 163, 9 where we read the description of a horse "with golden manes and iron feet and fast as mind[2]." From the passages quoted above it is evident that the use of iron and of iron weapons was well known in the Rigveda.

In the Black Yajurveda[3] is mentioned a remarkable kind of fire-weapon called Sūrmī which is defined by the commentator Shāyana as a "burning iron barrel." It is described as having a long bore inside the barrel and with its help hundreds could be killed at a time. The mention of an iron fire-weapon in Vedic literature shows the high quality of civilization prevalent amongst the ancient Aryan settlers.

In the White Yajurveda occurs the following passage in which six metals have undoubtedly been mentioned, viz. 'hiranya,' 'ayas,' 'shyām,' 'loha,' 'sīsa' and 'trapu.'[4] On further enquiry I find that the same passage occurs in the Taittiriya Samhita[5] and also in the Maitrāyanī Samhita,[6] with this difference that in the last-named Samhitā the word 'loha' has been replaced by the word 'lohitāyas' or 'red metal' meaning evidently copper. There is no difference of opinion regarding the meaning of 'sīsa' and 'trapu' which mean lead and tin respectively, but commentators are hopelessly at variance in their interpretations of 'ayas,' 'shyām' and 'loha.'[7] After reading these

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धमन्ति तद्वत्" । In Rig. VI. 3, 4 we have "द्रविः न द्रावयति" 'meaning as a melter causes to melt.'

1 Rig. VI, 75, 15, "यस्या अयोमुखं" which is commented upon by Shāyana as "यस्या इषोर्मुखमयोऽयोमयं भवति" ।

2 Rig. I, 163, 9 "हिरण्यशृंगोऽयो अस्य पादा मनोजवा अवर इद्रं आसीत् ।

3 एषा वै सूर्म्मी कर्णकावत्येतयाऽस्म

वै देवा असुराणां शततर्हां स्तृंहन्ति । Black Yajurveda, I, 5, 6, 7. Shāyana comments on the above thus "ज्वलन्ती लोहमयी स्थूणा सूर्म्मी । सा च कर्णकावती छिद्रवती, अतएव ज्वलन्ती । एकेन प्रहारेण शतसंख्याकान मारयन्तः शूराः शततर्हाः । असुराणां मध्ये तादृशान एतया अथवा देवाः वा हिंसन्ति" ।

4 हिरण्यञ्च मे अयश्च मे श्यामं च मे लोहञ्च मे सीसञ्च मे त्रपुच मे यज्ञेन कल्पन्ताम । XVIII, 13.

5 तैत्तिरीय संहिता, IV, 7, 5, 1.

6 मैत्रायणी संहिता, II, 11, 4, 5.

7 Mahidhar comments in the following manner on the passage in the White

commentaries I have formed the opinion that the passage refers to the following six metals, viz. silver (hiranya), gold (ayas), iron (shyām), copper (loha), lead (sīsa) and tin (trapu). The word 'hiranya' ordinarily means gold, but as the commentator Mahidhar points out that it means 'silver' also, I have preferred this meaning in order to make sense. Shāyana in many passages has taken 'ayas' for gold, and I have adopted his interpretation here. The word 'shyām' meaning 'black' evidently means iron, and the word 'loha' or 'lohitāyas' means, as has been pointed out, copper.

The most prolific mention of 'iron' or 'ayas' occurs in the Atharvaveda, the latest of the four Vedas. I would give below several amongst many such passages of the text together with Whitney's translation, which is the most literal of all translations of the Atharvaveda. In the passage Atharv. XI, 3, 1, 7[1] the word 'shyamamaya' is explained by Shāyana as 'black metal' or iron and the word 'lohita' as 'red metal' or copper. Whitney also remarks that "that is doubtless iron and copper respectively." In Atharv. V, 28, 1, while describing a formula for an amulet of three metals, 'harita' (gold), 'rajata' (silver) and 'ayas' (iron) are mentioned.[2] In VI, 63, 2 'bond-fetters of iron' are mentioned and in the next verse (VI, 63, 3) 'iron post' is referred to.[3] The word "ayodamstra" in VIII, 3, 2 has been rendered by Whitney as "thou of iron tusks," applying the epithet to Agni or fire. "Ayojālā" in XIX, 66, 1 has been translated by Whitney as 'metal nets' and 'ayashmayena ankena' in VII, 115, 1 as "with hooks of metal"; they can, however, be more appropriately translated as 'iron nets' and 'iron hooks' respectively. It

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Yajurveda "हिरण्यं सुवर्णं रजतं वा द्वयोनाकुप्ययोस्त्याभिधानात्। अयो लोहं। श्यामं ताम्रलोहं कांस्यं रजतं कनकं वा। लोहं कालायसे" Mādhabāchārya in his commentary on the Taittiriya Samhita says, "श्यामं कृष्णायसम्. लोहं कांस्यताम्रादि"। Macdonell and Keith have rendered 'ayas' as 'bronze' (Vedic Index pp. 31-32).

1 Atharvaveda, XI. 3, 1, 7, श्याममयोऽस्य मांसानि लोहितमस्य लोहितं।

2 हरिते त्रीणि रजते त्रीण्ययसि त्रीणि तपसाविष्ठितानि। Atharva V. 28, 1.

3 नमोऽस्तु ते निर्ऋते तिग्मतेजोऽयस्मयान्वि चृता बन्धपाशान्—VI, 63, 2 "homage be to thee, O Nirrti, thou of keen keenness, unfasten the bond-fetters of iron."

अयस्मये द्रुपदे बेधिष इहाभिहितो मृत्युभिर्ये सहस्रम् (VI, 63, 3)—"thou wast bound here to an iron post bridled with deaths that are a thousand"

will readily be seen that in the passages quoted from the Atharva-veda, the sense of iron makes more complete sense than any other metal. There can remain scarcely any doubt of the use of iron in Vedic times in various directions.

IRON IN THE BRAHMAN AGE (CIRCA 1000 B..C–500 B.C.).

In the Brāhmans and Upanishads, which belong to Vedic literature though later in date than the Vedas, the latest date of their composition being 800 B.C. to 500 B.C., we find that the word 'ayas' has been completely differentiated into 'krishnāyas' or black metal and 'lohitāyas' or red metal. Iron is thus referred to as 'krishnāyas' or 'kārṣnāyas' in Chāndogya Upanishad IV, 17, 7; VI, 1, 5; in Jaimini Upanishad Brāhmana III, 17, 3, in Taittiriya Brāhmana III, 62. 6, 5 and other places.[1] The distinction between iron and copper is explicit and complete.

[1] Macdonell and Keith, Vedic Index.

CHAPTER II.

IRON IN THE EPIC AGE (CIRCA 500 B.C.—200 B.C.)[1]

Coming to the Epic Age during which time the civilization of the Aryans had greatly advanced and become highly complex, we find the most extensive use of iron in the two celebrated Hindu epics, the Rāmāyana and the Mahābhārata (specially the latter), the greater portions of which are admitted to have been composed by the 4th century B.C. We find the most prolific mention of iron swords, spears, javelins, axes, arrows, maces and other numerous kinds of weapons of warfare, though the southern monkey hordes of Rāma fought in Ceylon with fragments of mountains and uprooted trees. The great iron 'gadā' or maces of Bhīma and Durjodhan as well as the story of the blind king Dhritarāstra's breaking to pieces in great agony the life-size iron statue of Bhīm, who had killed the hundred sons of the king in the great battle of Kurukhetra, are well known to every reader of the Mahābhārat. Mention may also be made here of the story in the Mushala Parva of the Mahābhārat, of the wicked descendants of the kings of the Yadu dynasty mocking the Rishis (sages) and of one of them giving birth to a big iron mace (mushal) through the curse of those Rishis, which, however, ultimately proved to be the engine of destruction of the entire family of the Yādavas. These stories naturally lead to the conclusion that the production of iron in India during the Epic Age was very considerable indeed or else the stories of the life-size iron statue of Bhīm or the iron mace would not have been possible.

Turning to the Laws of Manu[2] we find that the great Hindu

[1] Mr. R. C. Dutt takes the date of the Epic Age to be 1400—1000 B.C. We have adopted here the more moderate estimate.

[2] Manu's age does not seem to have been fixed definitely. Many authorities place Manu's Institutes before the Epics, but Macdonell says, "it (Manu's Institutes) is closely connected with the Mahābhārat of which three volumes alone (III. XII, XVI) contain as many as 260 of its 2684 slokas. It probably assumed

lawgiver mentions the use of household utensils made of copper, iron, bronze, brass, tin and lead and enjoins their purification with ashes, acid water and water.[1] He also prescribes that a thief who would steal precious stones and metals like copper, silver, iron and bronze, would, as a penalty, eat for twelve days small grains of rice.[2] Manu in the seventh canto of his Institutes gives elaborate descriptions how a king should construct several kinds of forts and equip them with iron swords, engines of warfare, arrows, and bows.

As regards ancient medical literature we find in the great medical work of Sushruta, who should have flourished in the 3rd or 4th century B.C., as can be guessed from the Bower manuscripts edited by Hoernle, elaborate description of nearly one hundred kinds of surgical instruments by means of which many major operations such as opening of the abdomen, eye operations, dissection of the fœtus, were performed. A great many of them must have been prepared from the best steel, for which India was so justly famous from time immemorial, as we find that the dissecting instruments had an edge which would be less than 'half of a piece of hair bisected longitudinally.' The instruments were used to be whetted on a stone having the colour of 'māskalāi' (a kind of black pulse).

Next coming to historical times we find Megasthenes, the celebrated Greek ambassador, who visited India in 302 B.C., bearing testimony to the fact that Indian soil had "underground numerous veins of all sorts of metals; for it contained much gold and silver and copper and iron in no small quantity, and even tin and other metals, which are employed in making articles of use and ornaments, as well as the implements and accoutrements of war." During the invasion of Alexander the Great in the 4th century B.C. the Indian King Porus, who was defeated, gave a present of 40 lbs. of steel to the Greek conqueror, showing in what high

its present shape not much later than 200 A.D."—"History of Sanskrit Literature," p. 428.

1 ताम्रायः कांस्यरैत्यानां त्रपुणः सीसकस्य च ।
शौचं यथार्हं कर्तव्यं क्षाराम्लोदकवारिभिः । Manu, V, 114.

2 मणिमुक्ताप्रवालताम्रस्य रजतस्य च ।
अयः कांस्योपलानाञ्च द्वादशाहं कणान्नता । Manu, XI, 168.

estimation was Indian steel held in Europe. Chānakya or Kautilya, the Indian Maichaveli and the well-known prime minister of Chandra Gupta, has in his well-known 'Treatise on Polity' (Arthashāstra) left a magnificent account of the political, industrial, social and military organization of the fourth century B.C. In it we not only find the description of various implements of warfare such as iron swords, arrows, shatagni (killer of hundreds), axes, spades, etc., besides iron breast-plates and armour, but also the description of the functions of an important state functionary called 'ākarādhwakhya' or 'superintendent of mines.' I have not come across this word in any other old Sanskrit writing, and the duties of this official show that there was formerly a regular government department responsible for mining work. The superintendent of mines should make trial borings "with the help of trained men who are versed in the knowledge about metals and distillation of mercury. He should be an adept in the examination of precious metals. He should be provided with necessary apparatus and make borings in those places where the presence of slag, charcoal and ashes indicates previous smelting operations or in those places, either in the plains or at the foot of mountains, where the colour or smell of soil and ores would suggest the existence of metals.[1]" Chānakya also gives descriptions of ores and mines of gold, silver, copper, iron, lead, tin and precious stones and mentions that the ores of iron should have a colour of the orange, faint red or red like vermillion.[2] The ores evidently refer to brown and red hæmatites (gairik) which are found abundantly in India.

Abundant evidence has been quoted above to show that the use of iron was common in India from 2000 B.C. to the fourth century B.C. I shall purposely avoid referring to the later Purānas and Sanskrit literature as we find that from the first or second century after Christ not only iron was being used in the arts and industries but also in internal use as a medicine. The great religious

[1] आकराध्यक्षः शुल्बधातुशास्त्ररसपाकमणिरागज्ञस्तज्ज्ञसखो वा तज्जातकर्मकरोपकरणसम्पन्नः किट्टमूषाङ्गारभस्मलिङ्गं वा आकरं भूतपूर्वमभूतपूर्वं वा भूमिप्रस्तररसधातुमत्यर्थवर्णगौरवम् उग्रगन्धरसं परीक्षेत— कौटिलीयं अर्थशास्त्रम् Edited by R. Sham Sastri, p. 81.

[2] कुरम्भः पाण्डुरो हितसिन्दुवारपुष्पवर्णो वा तीक्ष्णधातु—p. 83.

reformer and alchemist Nāgārjuna who flourished in the middle o the second century A.D. discovered the process of "killing" iron and other metals and even introduced mercury preparations for internal use. Moreover in spite of the fact that iron rusts very easily, so many archæological specimens of iron of great antiquity are found throughout India that these specimens, alike remarkable for massiveness and age, show the use of iron in India on a very extensive scale and in all ages. We would now proceed to describe some of the important archæological specimens of iron found in different parts of India.

CHAPTER III.

Ancient Specimens of Iron in India.

PREHISTORIC IRON IMPLEMENTS DISCOVERED IN TINNEVELLY.

A very remarkable and large number of prehistoric iron implements such as swords, daggers, tridents, spears, javelins, arrows, spades, hangers, saucer lamps, beam rods and tripods has been unearthed during the excavation of numerous burial sites in the gravelly mounds of the Tinnevelly district of the Madras Presidency, adjoining the valley of the Tāmraparni river.[1] The age of these burial sites cannot be ascertained with anything approaching approximation as the burial urns must have been sunk inside the earth in an age when the custom of cremation was not introduced into Southern India. The Pandiyan Kingdom existed from a very early time, and is referred to in an Asoka inscription 250 B.C. in Northern India.[2] The Pandyas were also known to the Sanskrit grammarian Kātyāyana whose date probably is not later than the fourth century B.C. Earlier and later writers mention them. In the Rāmāyana and Mahābhārat, the Pandiyans, Dravidas and Cholas are mentioned. The Pandiyans were in possession of the Tinnevelly district from the earliest historical times.[3] The original line of kings seems to have continued down to their conquest by Rajendra Chola in A.D. 1064. It would be hazardous to guess if urn burial was prevalent during the reign of the earliest Pandiyan kings, the custom of burial being supplanted by cremation later on.

However the most extensive prehistoric burial site was at Ādittanattur. The funeral urns were large, one-legged, elongated, globular pots of thick red earthenware, averaging less than a yard

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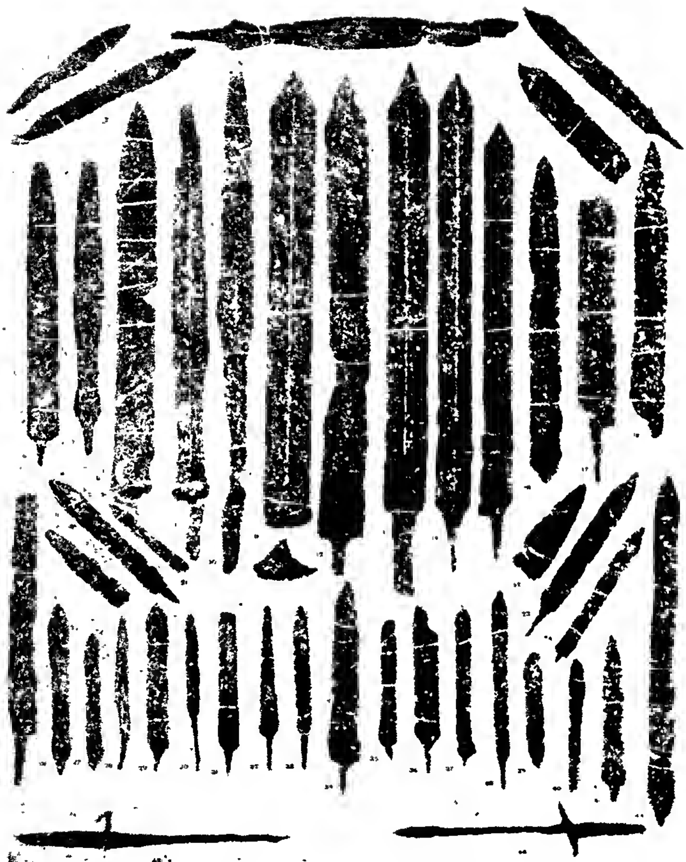
[1] A. Rea's "Prehistoric Antiquities in Tinnevelly," Annual Report of Arch. Survey of India, 1902-3, 111–140.

[2] Sewell's Lists, II, 221.

[3] Sewell's Lists, I, 303.

PLATE I



Prehistoric Antiquities in Tinnevelly:
Iron Swords and Daggers

(Annual Report, Archaeological Survey of India, 1902-3, page 132.)

in diameter by a slightly greater height. All the urns had flat conical covers and contained skulls or bones of a skeleton accompanied with articles of pottery and of metals such as gold, bronze and iron. The gold ornaments were oval diadems which appear to have been fastened to the forehead of a corpse. The bronzes exhibit a high degree of skill in workmanship and used for ornamental purposes in the shape of vase stands, bowls, jars and cups. No stone implements of the palæolithic or næolithic age were found. The iron implements and arms were generally found outside the urns with their points downwards, showing that they were thrust into the earth by the attendant mourners. Many of the iron implements were deeply corroded, while others were fairly well-preserved. The swords were generally two feet or two feet four inches long and about two inches broad, the blades being all double-edged. They had a spike or an iron handle at the hilt which was attached to a wooden handle, the latter having decayed in most cases through age. A collection of these swords and daggers is shown in the annexed plate. In the plate Nos 1, 2, 4, 19, 20, 21, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40 are daggers and the rest are swords. The daggers were generally eight to twelve inches long and one to one half inch broad. Besides these weapons numerous axes, spades, arrows, javelins, lances and iron lamps were also found, showing that iron was used in those remote times in making implements of every description. The nature of the iron has not been determined. Southern India was famous from remote times for its steel called "wootz," and it would not be a surprise if this very remarkable collection of ancient weapons and implements turns out on examination to be specimens of steel, though the chances are that these weapons were made of wrought iron.

IRON FROM THE PIPRĀHWĀ STUPA.

In January 1898, Mr. William Peppe, a landholder of Birdpur in the Basti district, excavated an old stupa near the village of Piprāhwā [1] situated on his estate half a mile from the Nepal

[1] Journal Royal Asiatic Society, 1898, pp. 573–588, and p. 388. *Ibid.*, 1899, p. 570.
Indian Antiquary, 1907, XXXVI, p. 117.

frontier and fourteen miles south-east of the ruins at Kapilāvastu. During the excavations a big stone-coffer was discovered, containing inside two vases, one lotā and one box, all made of soap-stone together with a beautiful crystal bowl with a fish handle and numerous cut stones, and gold stars and leaves. The relic urns contained pieces of bone, which, from an inscription on one of the vases, were supposed to be the bones of the "divine Buddha" (the bones were subsequently presented to the King of Siam). Mr. Peppe also discovered in the building to the east of the stupa several objects of iron, viz a small iron spear-head, with blade measuring $3\frac{1}{4}'' \times \frac{7}{8}'' \times \frac{1}{8}''$, and handle measuring $4\frac{1}{2}''$, also an iron spike, nails with large heads and sundry pieces of iron. The Piprāhwā vases as well as four iron pieces, viz. the spear-head, two nails of ordinary size and one curved iron spike longer than the nails have been preserved in the Indian Museum, Calcutta. The inscription is regarded as older than the reign of Asoka, being circa 450 B.C., but the iron articles were not found inside the stone-coffer but in the monastery to the east of the stupa, which Vincent Smith recommended to excavate as he hoped that objects of interest and inscriptions might be obtained. The monastery was possibly erected a few centuries later, and we may regard the iron articles to be specimens of the first or second century A.D.[1] The author has seen these articles; the spear-head has rusted considerably but the nails have been very well preserved. The nails show distinct signs of hammering and it is wonderful to see that they have been preserved so well. The iron is undoubtedly wrought iron.

IRON IN THE BUDDHIST TEMPLE AT BODH-GAYA.

Iron has been discovered while excavating the foundations of the celebrated stupa at Bodh-Gaya and also as clamps in the adjoining temples. As the present custom is to preserve newspapers and coins when laying foundation stones of public build-

[1] The authorities of the Indian Museum, Calcutta, should note down in the almirah in which the Piprāhwā finds are exhibited that the iron articles were obtained in the monastery east of the stupa and not inside the stone-coffer. As exhibited at present the unwary observer will run away with the impression that the iron articles were found in the stone-coffer and therefore belong to the fifth century B.C.

PLATE II

Iron Clamps at Bodh-Gaya

(Photograph by the Author.)

ings, the ancient custom was also similar in this respect, as various coins, precious stones, metals like gold, silver, copper, iron have been discovered while excavating the foundations of old temples and monasteries. The stupa of Bodh-Gaya is a venerable one. Hoean Thsang described it in his travels.[1] The stupas have multiplied since Asoka first built a Buddhist bihār in Bodh-Gaya (3rd century B.C.). Afterwards the bihār was converted into a temple. General Cunningham was of opinion that the temple was constructed by King Huviska and that it was expanded in the fourth century. Fergusson, however, is of opinion that it was constructed in the 6th century.[2] However, the Asoka foundations of the stupa, on excavation, has yielded a piece of iron slag which has been preserved in the Calcutta Museum.[3] This piece of iron slag is, I believe, the most ancient archaeological evidence of a historical nature of the manufacture of iron in India as early as the third century B.C. Besides the iron slag many iron clamps five or six inches long and about ½ inch broad have been found in the main temple and various stupas in Bodh-Gaya and preserved in the Indian Museum. They have greatly rusted. Such iron clamps have largely been used in the temples at Puri, Bhubaneswar and Konarak in Orissa from the sixth to the twelfth century. On account of the antiquity of the Bodh-Gaya temple the iron slag and the iron clamps are important in the history of the manufacture of iron in ancient India, being specimens of the 3rd century B.C. to the 6th century A.D. I am not aware of any analysis of the iron, but there is little doubt that the iron is wrought iron.

IRON PILLAR AT DELHI.

This celebrated iron-pillar stands in a quadrangle adjoining the famous Kutub Minar, which is situated in a village called Mihrauli (Mihirapuri) about 12 miles from the city of Delhi. It stands about 22 ft. above the ground, and exact excavations

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[1] Beal's Buddhistic Records, Vol. II, pp. *118-121*.

[2] Fergusson, Indian and Eastern Architecture, New edition (1910), Vol. I, p. 77.

[3] Catalogue and Hand-book of Archaeological Collections in the Indian Museum by John Anderson, Part II. p. 67.

have shown that it goes about 20 inches below the ground. Roscoe and Schorlemmer, while admiring the metallurgical skill of the ancient Hindus, have repeated the original mistake of General Cunningham in thinking it to be 60 ft. in length, while as a matter of fact it is 23 ft. 8 in. long. Writes Fergusson: "It is a curious illustration how difficult it sometimes is to obtain correct information in India, that when General Cunningham published his reports in 1871, he stated, apparently on the authority of Mr. Cooper, Deputy Commissioner, that an excavation had been carried down to a depth of 26 ft. but without reaching the bottom. The man in charge, however, assured him that the actual depth reached was 35 ft. (Vol. I, p. 169). He consequently estimated the whole length at 60 ft., but fortunately ordered a new excavation, determined to reach the bottom and found it at 20 inches below the surface (Vol. IV, p. 28). At a distance of a few inches below the surface it expands in a bulbuous form to a diameter of 2 ft. 4 in. and rests on a gridiron of iron bars, which are fastened with lead into the stone pavement." [1]

The diameter of the pillar at the lower end is 16·4″ and towards the top at the capital 12·05″. The capital which is engraved and of the bull pattern is 3 ft. 6 in. in length. The weight is estimated to exceed six tons.

There is an inscription on the pillar which is unfortunately undated, being a posthumous eulogy in verse of a king named Chandra. The script as well as the text of the inscription have served as a clue to the fixation of the date of the construction of the pillar. Prinsep was of opinion that the script was of the 3rd or 4th century A.D., while Bhai Daju held that it was of the end of the fifth or the beginning of the sixth century. Fergusson supposes it to be the work of some of the Chandra Rajas of the Gupta family and places it in 363 or 400 A.D. Dr. Hornœle judges the characters to be of the Gupta variety of the North-Eastern alphabet and unhesitatingly ascribes the iron pillar to Chandra Gupta II and assigns it the approximate date of 410 A.D.[2] Dr. Hornœle's opinion is fully confirmed by Vincent Smith

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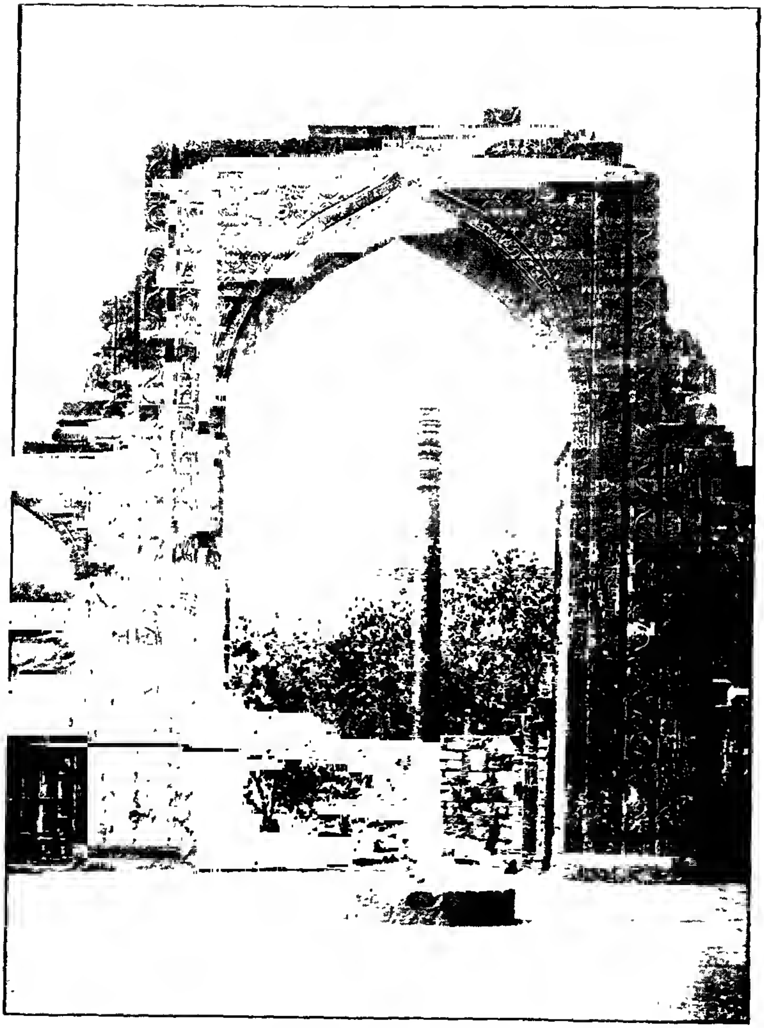
[1] Fergusson, History of Indian and Eastern Architecture, Vol. II, p. 279.

[2] Indian Antiquary, Vol. XXI, pp. 42-44.

PLATE III



Iron Pillar at Delhi.

(Photograph by Johnston and Hoffmann, Calcutta.)

who on the examination of the text of the inscription has also come to the conclusion that the King referred to is no other than Chandra Gupta II. We give below a translation of the inscription as given by Dr. Fleet and modified by Vincent Smith.[1] "The lofty standard of the divine Vishnu was erected on Mount Vishnupada by King Chandra, whose thoughts were devoted in faith to Vishnu. The beauty of that king's countenance was as that of the full moon; —by him, with his own arm, sole world-wide domain was acquired, and long held; and although, as if wearied, he has in bodily form quitted this earth, and passed to the other-world country won by his merit, yet like the embers of a quenched fire in a great forest, the glow of his foe-destroying energy quits not the earth; by the breezes of his prowess the southern ocean is still perfumed;— by him, having crossed the seven mouths of the Indus, were the Vahlikas vanquished in battle; and when warming in the Vanga countries he breasted and destroyed the enemies confederate against him, fame was inscribed on [their] arm by his sword." The facts recorded in the inscription thus are that the pillar was erected in honour of Vishnu on Mount Vishnupada (Vishnu's foot) by a monarch named Chandra, who had long enjoyed world-wide sovereignty, but was deceased at the time when the inscription was engraved, and that this sovereign defeated a hostile confederacy in the Vanga countries, and had, after crossing the seven mouths of the Sindhu or Indus, vanquished the Vāhlikas. Vincent Smith is convinced that the emperor referred to in the inscription is no other than Chandra Gupta II, in whose reign the Gupta empire attained its climax. Chandra Gupta II died in A.D. 413, and the posthu-

[1] Vincent Smith: Journal, Royal Asiatic Society, 1897. p. 6 Vincent Smith writes: "The word *bhāvēna*, which we translate 'in faith.' is actully *dhāvēna*. The earlier translators regarded this word as a proper name, and supposed the name of the king commemorated to be Dhāva. But the construction of the sentence scarcely admits of this interpretation. The use of the two names Dhāva and Chandra for the one person in such a brief record, without a word of explanation or amplification, would be intolerably harsh composition, and it is to my mind quite incredible that the writer intended to give the king two names. The correction from *dhāvēna* to *bhāvēna* appears to be both necessary and certain. The error is easily explained by the fact that a very slight slip of the engraver's tool was sufficient to convert the character nsed for *bh* into a form which may be read as *dh*."

mous inscription, which was presumably executed by his successor soon after his decease, must be dated not later than A.D. 415. This determination settles within a year or two the date of a very remarkable and interesting monument which has always attracted the attention of all travellers.

There is another thing in connection with the erection of this pillar which is of great importance. The inscription says that the pillar was erected on a *hill* called Vishnupada, whilst as a matter of fact the place in which it stands at present is a level country. Vincent Smith contends, and there is evidently much force in his contention, that the pillar was originally erected in some other place which "must have been a well-known spot frequented by Vaishnava pilgrims, within the Gupta dominions and not very remote from Delhi. All the conditions of such a place are satisfied by Mathurā" which is less than eighty miles from Kutab Minar. Vincent Smith supposes that "the Katra Mound, where the magnificent temple of Vishnu, under the name of Keshava, once stood, may very probably prove to be 'Vishnupada giri,' the mount of Vishnu's footmark, mentioned in the inscription." He also concludes that the pillar was removed to its present site by Ananga Pal II in or about A.D. 1050 when he founded the city of Delhi *de novo*. This conclusion is supported by the comparatively new structure of the platform on which the pillar is erected as well as the fact that there is another inscription on the pillar itself in which Ananga Pal announces the date of the foundation of Delhi by himself.

For some time there existed a good deal of misconception regarding the composition of the material of which the pillar was made. There was a local tradition that it was made of "saptadhätu" or seven metals, and from the peculiar yellow colour of the top of the pillar many people supposed it to be a casting of brass or copper. All doubts were removed when General Cunningham had two specimens of the metal analysed, one by Dr. Murray Thomson of the Roorkee Engineering College and the other by Dr. Percy of the School of Mines. Both found it to be wrought iron without an alloy. The specific gravity of the metal was 7·66, that of purest wrought iron being 7·84. Quite recently a complete analysis of the metal has been published by Sir Robert

Hadfield,[1] who found its specific gravity to be 7·81. The results of analysis are:—

Iron	.. ..	99·720 per cent.
Carbon	.. ..	·080 ,,
Silicon	.. ..	·046 ,,
Sulphur	.. ..	·006 ,,
Phosphorus	.. ..	·114 ,,
Manganese	.. ..	*Nil* ,,
	Total ..	99·966

The analysis shows that the metal was pure wrought iron having no manganese, "a somewhat special point, as wrought iron usually contains manganese." The low proportion of sulphur shows that the fuel employed must have been charcoal and that the ores must also have been pure. It will be explained later on that probably "high phosphorus and low sulphur and manganese" have contributed to the capacity of the iron in resisting the rusting influence of rain and wind for full fifteen centuries.

This remarkable monument of the metallurgical skill of the ancient Hindus has won the unstinted admiration of all who have seen it. Chemists, archæologists, travellers, engineers and geologists are unanimous in pronouncing this pillar of wrought iron as unique in the annals of metallurgy in the four quarters of the globe. We cannot do better than conclude our account of this pillar with quotations from the opinions of some of these expert observers.

Roscoe and Schorlemmer in their well-known "Treatise on Chemistry" have remarked that "the dexterity exhibited by the Hindus in the manufacture of wrought iron may be estimated from the fact of the existence in the Mosque of the Kutub near Delhi of a wrought iron pillar no less than 60 feet in length. This pillar stands about 30 feet out of ground and has an ornamental cap bearing an inscription in Sanskrit belonging to the fourth century. It is not an easy operation at the present day to forge such a mass with our largest rolls and steam hammers; how this

[1] Journal of the Iron and Steel Institute, 1912, Vol. 85, No. 1, p. 170 (slip).

could be effected by the rude hand-labour of the Hindus we are at a loss to understand." Though the two distinguished chemists have made a mistake, as has already been pointed out, in thinking that the Delhi pillar is 60 feet high, while as a matter of fact its height is 23 feet 8 inches, nevertheless their eulogy is thoroughly well-deserved. Roscoe and Schorlemmer were evidently ignorant of the existence of the Dhar pillar, which is 43 feet 8 inches long, and the numerous iron girders in the temples of Orissa, some of which are even 35 feet in length. These gigantic beams and pillars were constructed, as has been explained afterwards, by forging small blooms of wrought iron.

Fergusson, the great archæologist, has written "Taking A.D. 400 as a mean date—and it certainly is not far from the truth—it opens our eyes to an unsuspected state of affairs to find the Hindus at that age capable of forging a bar of iron larger than any that have been forged even in Europe up to a very late date, and not frequently even now. As we find them, however, some centuries afterwards, using bars as long as this in roofing the porch of the temple at Kanarak, we must now believe that they were much more familiar with the use of this metal than they afterwards became. It is almost equally startling to find that after an exposure to wind and rains for fourteen centuries, it is unrusted, and the capital and inscription are as clear and as sharp now as when put up fifteen centuries ago."[1]

The opinion of two engineers is given below. One engineer says, "Nothing heretofore brought to light in the history of metallurgy seems more striking to the reason as well as the imagination, than this fact that from the remote time when Hengist was ruling Kent and Cedric landing to plunder our barbarous ancestors in Sussex down to that of our Third Henry, while all Europe was in the worst darkness and confusion of the Middle Ages—when the largest and best forging producible in Christendom was an axe or a sword blade—these ancient peoples in India possessed a great iron manufacture, whose products Europe even half a century ago could not have equalled." Another engineer's opinion will also be found to be interesting—" while considering forging of large masses of iron

[1] Fergusson, "History of Indian and Eastern Architecture," Vol. II, p. 280.

and steel, it is not easy to forget the impression caused by first seeing the iron pillar at Delhi. This column of wrought iron which is 16 inches in diameter, of which 22 feet are above the ground, and which is said to be 50 feet long and weighing about 18 tons, is finished perfectly round and smooth, with an ornamental top, and was made many centuries ago from iron produced direct from the ore and built up piece by piece. Remembering the lack of facilities men had in those days for first forging and then welding together such an enormous mass makes one wonder at the iron worker of those days, who must have possessed engineering ability claiming the admiration of our times. It is questionable whether the whole of the iron works of Europe and America could have produced a similar column of wrought iron so short a time ago as the exhibition of 1851.''[1]

IRON BEAMS IN THE TEMPLES AT BHUBANESWAR, PURI AND KONARAK IN ORISSA.

Orissa is famous for her temples. The magnificent temple at Bhubaneswar, the black pagoda of Konarak, and the white pagoda of Puri are remarkable specimens of Hindu architecture of the Middle Ages. Of these gigantic temples the one at Bhubaneswar is the oldest, being constructed in A.D. 640. The temple of Puri was built in the 12th century (A.D. 1174). From architectural considerations Fergusson was of opinion that the black pagoda at Konarak, which was so similar in workmanship to the great temple at Bhubaneswar, must have been built two or three centuries after the Bhubaneswar temple, but certainly before the time of the erection of the Puri temples. Mr. Bishan Swarup in his excellent work on the Konarak temple concludes after a careful examination of old records and literature on the subject "that the temple of Konarka was built by Purandra Kesari in the latter half of the 9th century and its Nātmandir was constructed in A.D. 1241 by Raja (Nagroo) Narsinha Deva of the Gangetic dynasty."[2]

A very remarkable thing regarding these temples is the exten-

[1] Presidential address to the Institute of Mechanical Engineers, London, 1905.

[2] Bishan Swarup, Konarka—the black pagoda of Orissa, p. 72

sive use of iron beams in supporting the roofs and for other purposes. At Bhubaneswar "in the joining of long projecting cornices and roof stones iron clamps were frequently employed"[1] and iron beams also may be seen in great abundance.

At Puri iron beams have been much more extensively used and ore of larger dimensions. In the Gunduchibāri or Garden Temple at Puri, where the images of Jaggernāth and his brother Balarām and sister Subhadrā are taken after the car festival in June or July for ten days, as many as 239 iron beams ranging up to 17 feet long and up to 6 by 4 or 5 by 6 inches section have been counted. We give a list of these iron beams prepared by Mr. N. C. R. Chaudhuri, the District Engineer at Puri, and quoted by Mr. H. G. Graves.[2]

Number of Beams at the Lintels of the Doors.

Item 1	12
,, 2	38
,, 3	45
Total	95

Number of Beams below Temple, Pillar Plates, etc.

Item 4	16
,, 5	112
,, 6	14
Total	144
Grand Total	239

[1] Rajendra Lall Mitra, "Antiquities of Orissa," Vol. I, p. 36.

[2] H. G. Graves, "Journal of the Iron and Steel Institute," 1912, Vol. LXXXV, No. 1, p. 200–2.

1. *At the Lintels of Doors in the Outer Compound Wall.*

	No.	Length		Breadth.	Height.
		Ft.	In.	Inches.	Inches.
Back door ..	1	10	5	3	4
	2	7	7	3	4
,, ,, ..	1	9	8	3	4
	1	8	5	3	4
Front door	2	11	4	5	3
	2	9	8	5	3
,, ,, ..	2	8	0	5	3
	1	12	6	5	3
	12				

2. *At the Lintels of the Outer Doors of the Garden Temple.*

	No.	Length.		Breadth.	Height.
		Ft.	In.	Inches	Inches.
Door ..	2	5	0	5	3
	2	6	7	5	3
,, ..	2	7	6	6	4
	2	9	8	6	4
	2	6	8	6	4
,, .	1	5	0	6	4
	1	5	0	3	4
,, ..	1	6	8	3	4
	2	5	0	4	3
,, ..	1	5	0	4	4
	2	4	2	4	4
,, ..	2	6	9	5	4
	2	5	0	5	4
,, ..	2	9	8	5	5
	2	7	6	5	3
,, ..	2	6	8	4	4
	2	5	0	5	3
,, ..	2	6	4	4	3
	2	5	0	4	4
,, ..	2	6	4	4	3
	2	5	0	3	3
	38				

3. *At the Lintels of the Inner Doors of the Garden Temple.*

	No.	Length.		Breadth.	Height.
		Ft.	In.	Inches.	Inches.
	1	9	0	5	5
Door ..	2	7	0	4	3
	3	10	3	5	4
,, ..	2	6	3	4	3
	2	5	0	4	3
,, ..	2	7	6	4	3
	2	5	9	4	3
,, ..	2	5	2	4	3
	2	4	0	4	3
,, ..	2	4	7	4	3
	2	3	6	3	3
,, ..	2	5	6	4	3
	2	4	6	4	3
,, .	2	4	8	4	3
	2	3	6	4	3
	2	9	2	5	4
,, ..	2	7	0	4	4
	1	10	5	5	4
,, ..	2	8	0	3	4
	2	6	9	3	3
,, ..	1	4	9	3	2
,, ..	1	4	9	3	2
,, ..	1	3	6	3	2
,, ..	1	4	3	3	3
,, ..	1	4	3	3	3
,, ..	1	4	6	3	3
	45				

4. *Pillar Plates (within the temple).*

No.	Length.		Breadth.	Height.
	Ft.	In.	Inches.	Inches.
12	17	2	5	4
4	10	10	5	4
16				

5. *Beams below Temple.*

No.	Length.		Breadth.	Height.
	Ft.	In.	Inches.	Inches.
7	6	0	5	4
53	3	0	3	3
16	2	0	3	3
17	3	0	3	3
2	1	6	3	3
1	1	0	3	3
16	2	0	3	3
112				

6. *Beams at the Corner of the Temple Room.*

No.	Length		Breadth.	Height.
	Ft.	In.	Inches.	Inches.
4	2	0	3	2
4	1	0	3	2
4	2	0	3	2
4	1	0	3	2
16				

From the enumeration of as many as 239 iron pieces in the Gunduchibāri Temple it is certain that iron beams have similarly been used on an extensive scale in the main temple itself.

At Konarak the beams are even larger in dimensions. Stirling, who visited the shrine in 1824, saw nine iron beams nearly one foot square and 18 to 21 feet long.[1] Fergusson, who visited Konarak in 1838, makes the section less, viz. 8 inches by 9 inches, but the lengths greater to 23 feet. Dr. Rajendra Lall Mitra makes the length of the beams 21 feet with average cross section 8 inches by 10 inches. The Konarak temple was more or less in complete ruins until regular work of preservation, commenced under the Government of Sir John Woodburn, Lieutenant-Governor of Bengal (Orissa was then a part of Bengal). Only a heap of debris and the dilapidated porch in the front remained while the Nāt-

[1] Stirling, Asiatic Researches, Vol. XV, p. 330.

mandir and other temples were buried under drift sea-sand probably two or three centuries previously. In 1901 the excavation of sand round the main temple was commenced and beautiful carvings and other objects of architectural value, including iron beams, were discovered. Whilst Stirling saw in 1824 only nine beams, Mr. H. B. Graves has counted in 1912 as many as twenty-nine beams at Konarak, the largest being 35 feet long and 7 to 7½ inches square, weighing about 6000 lbs. There is another beam 23½ feet in length and 11 by 10½ inches in section which was a part of a much longer beam, the other end missing. "Some of the pieces are only 5 or 6 feet in length and, could they be matched, it would probably result in not fewer then twenty complete beams."

The forging of the Orissan beams is not so perfect as in the case of the Delhi pillar, the weld lines being more or less perfectly visible and cinder lines and cinder more or less apparent in many beams.[1]

The iron used is undoubtedly pure wrought iron. I was given for analysis a specimen of Konarak iron—a detached piece from a beam, in an excellent state of preservation—by the Varendra Research Society.

A small piece of it could be easily flattened out into a thin sheet showing it to be wrought iron. The results of analysis are below.

Specific gravity 7·8.

Iron (estimated directly)	99·64 per cent.
Carbon	traces.
Sulphur	traces.
Phosphorus	·15 per cent.
Manganese	nil.
	99·79

The nature of the iron is almost similar to the iron of the Delhi pillar, manganese being absent and phosphorus high with traces of carbon and sulphur.

[1] The photograph and the diagram in Plate IV are reproduced by permission of the Secretary of the Iron and Steel Institute. The beam against which the walking stick stands is deeply corroded with holes into which a stick could be thrust.

PLATE IV

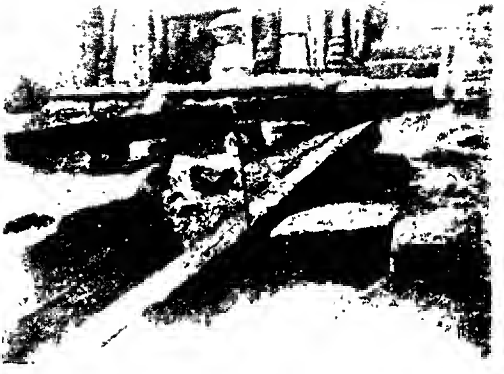


Fig. 1. Iron Beams at Konarak.

(Journal, Iron and Steel Institute, 1912, No. 1, page 105.)

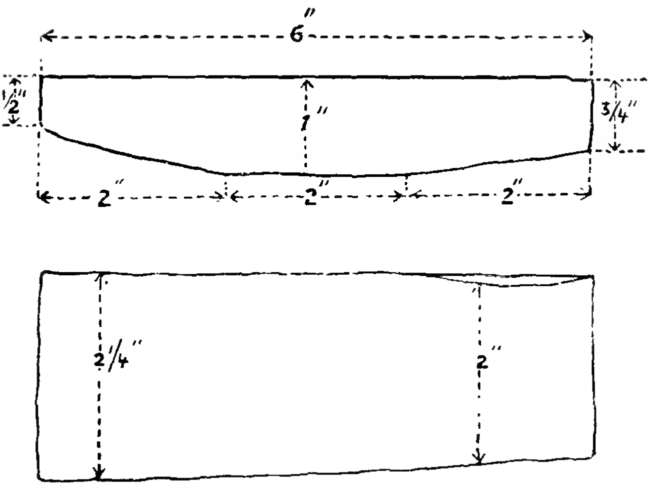


Fig. 2 Blooms in Konarak Iron.

(Journal, Iron and Steel Institute, 1912, No. 1, page 107.)

THE IRON PILLAR AT DHAR.

Besides the celebrated pillar at Delhi there exist two other iron pillars in India, viz. at Dhar, the ancient capital of Mālava, and on Mount Abu in Rajputana, respectively, to which I would like to attract the attention of the scientific world. Fergusson[1] in his "History of Indian and Eastern Architecture"; Vincent Smith[2] in his article "The Iron Pillar at Dhar," and Barnes[3] in his "Dhar and Mandu" have already dwelt on the subject of the great iron pillar at Dhar, whilst a full account of this pillar has been given by Mr. H. Cousens in the annual report of the Archaeological Survey of India, 1902-3 (pp. 205—212), and a translation of Akbar's Persian Inscription has been given in "Epigraphica Moslemica."[4] It is rather strange that the attention of the scientific world has not sufficiently been drawn to this pillar as in the case of the one at Delhi, though as regards dimensions the Dhar pillar comes to be the bigger of the two, the former being 43' 8" long and the latter 23' 8". Vincent Smith has rightly remarked, "Whilst we marvel at the skill shown by the ancient artificers in forging a great mass of the Delhi pillar, we must give a still greater measure of admiration to the forgotten craftsmen who dealt so successfully in producing the still more ponderous iron mass of the Dhar pillar monument with its total length of 42 feet."

The reason, I believe, why the Dhar pillar has hitherto failed to receive its due share of praise is that it is lying broken in three pieces, of which the first and largest is 24 feet 3 inches and is square in section. It could be seen half buried near the northern gate of the "Lat Masjid" of Sultan Dilwar Khan (1405 A.D.). The second one, 11 feet 7 inches long, now lies in the courtyard of the Ananda High School; its shape is not uniform throughout, 8 feet 6 inches being square and 3 feet 1 inch octagonal. The third piece is remaining imbedded within the masonry foundations of the public garden named Lalbag and is 7 feet 6 inches long and rectangular almost throughout its length. The average width is 10¼ inches.

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1 Fergusson, History of Indian and Eastern Architecture, revised by Messrs Bergess and Spiers (new Edition), Vol. II, p. 247.

2 Vincent Smith, Journal Royal Asiatic Society, 1898.

3 E. Barnes, Journal Bombay Branch of the Royal Asiatic Society, Vol. XXXI.

4 Epigraphica Moslemica, 1909-10, p. 13.

One end of the largest piece, which was originally the base, is bulbuous like the base of the Delhi pillar, about 20 inches having been imbedded in stone which in turn is fastened within iron bars. A fourth piece seems to be missing, as judged from the proportions of the square and octagonal sections, so that the original total height of the pillar was something like 50 feet. The pillar holds on one of its surface Akbar's Persian inscriptions, while Devnagri letters of the 14th century are chiselled here and there. Several small holes, measuring from $1\frac{3}{4}$ inches to 3 inches, surround the pillar, but they are not equidistant from each other. The weight of the pillar is estimated to be 7 tons, one ton greater than the weight of the Delhi pillar.

There exists a diversity of opinion regarding the object of the erection of this pillar. Fergusson holds that the pillar is not a pillar of victory like the Delhi pillar, but served some useful purpose like the iron beams at Konarak, as otherwise it would have been round throughout or have contained an ornamental capital.[1] Cousens on the other hand takes it to be a "jayasthambha" (pillar of victory) and I think Cousens is right in his opinion for the following reasons :—

(1) Of the three iron-pillars which have hitherto been discovered two have undoubtedly been pillars of victory, the probability therefore is that the Dhar pillar is similarly a jayasthambha.

(2) The lower part of this pillar is a little flat and bulbuous like the Delhi pillar and is enclosed in stone and iron bars to have it buried, so the probability of its being used as a beam like those of Konarak is very small indeed. Moreover there are many beams at Konarak, Puri and Bhubaneswar, while it is difficult to imagine how one pillar could be used for mechanical purposes.

(3) Fergusson's main objection is the absence of architectural work. Engravings on iron, it must be borne in mind, is not so easy as on stone, but there should exist, as a matter of course, some distinctive figure to mark a pillar as one of victory, as for example there is a "trishul" (trident) on the iron pillar on Mount Abu. It is very probable that a capital with a figure adorned the summit of this pillar as Mr. Lenny, Director of Public Instruction,

[1] Fergusson, History of Indian and Eastern Architecture, Vol. II.

PLATE V

Iron Pillar at Dhar.

(Annual Report, Archaeological Survey of India, 1902-3, page 206.)

Sindh, obtained a capital stone near it which probably was the receptacle of a figure of "Garur," which used to be engraved on the coins of the Hindu Kings of Mālava.

(4) Some have gone so far as to suggest from the small holes on the sides of the pillar that it was used as a "dipdān" (lamp-post). This suggestion is negatived by the fact that dipdans hitherto discovered are all made either of stone or bricks, but not of iron. Moreover the holes would have been equidistant if the pillar was really a lamp-post. Considering the unequal intervals between the holes, Cousens supposes that these pits were used for the purpose of inserting some instrument like crowbars while the pillar was being forged and welded.

The reasons stated above naturally lead one to the conclusion that the pillar was really a pillar of victory.

As regards the date of its erection, Vincent Smith supposes that like the Delhi pillar, the one at Dhar was also erected during the time of the Gupta Emperors.[1] This statement has not however been corroborated by any other authority.

The Moghul Emperor Jehangir in his autobiography writes: "Outside this fort (of Dhar) there is a Jāmi Masjid and a square pillar lies in front of the Masjid with some portions imbedded in the ground. When Bahadur Shah conquered Mālava he was anxious to take the pillar with him to Guzerat. In the act of digging out, it fell down and was broken into two pieces (one piece 22 feet long and the other 13 feet). I (Jehangir) have seen it lying on the ground carelessly and so ordered the bigger piece to be carried to Agra, which I hope to be used as a lamp-post in the courtyard of my father's (Akbar's) tomb."[2] Obviously Jehangir's orders were not carried out, though we learn that the pillar was broken in the act of uplifting it during Bahadur Shah's invasion of Mālava. Akbar's inscriptions only show that the Emperor approached Dhar at the time of conquering the Deccan. One fact however is certain, viz. that Dilwar Ghori gave the name "lat Masjid" to the mosque erected by him after the "lat" or pillar in front of it. Sultan Dilwar Ghori ascended the throne of Mālava in 1401 A.D., so that the

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1 Vincent Smith, Journal Royal Asiatic Society, 1898.

2 Tuzzuk-i-Jehangiri, pp. 201-2.

'lat' must have been in existence at least two or three centuries before, so that the approximate date of its erection may be taken as the twelfth century A.D. Fergusson from an examination of its mode of construction holds that it is a work of the tenth or eleventh century.[1] Local tradition points to Raja Vikramaditya or Raja Bhoja of Malava as the King during whose reign the pillar was erected,[2] whilst Cousens says that Raja Arjunvarma Deb built this pillar with the molten implements of war left in the battlefield by his enemies during his attack on Guzerat as a mark of victory in 1210 A.D. We would not however be far wrong in concluding that the Dhar pillar was erected in the twelfth century.

I am not aware of any analysis of the iron of this pillar. Local tradition states that it is made of seven metals (saptadhātu), but such tradition was also current at Delhi also. If Cousen's theory be true, viz., that the pillar was made by melting down the weapons left by the enemy, then the pillar should be made mainly of steel. As a proof of this theory white shining patches are shown on the pillar as indicating silver obtained from the silver hilts of swords. Such a theory on the face of it is improbable, as such an enormous column of steel was incapable of being forged. This pillar like the one at Delhi is undoubtedly made of wrought iron and in a similar manner.

In concluding my observations on the Dhar pillar, I would request the Archaeological Department of India to have the iron analysed and also to build up the entire pillar into one whole by putting the broken pieces over one another. It must not be forgotten that the Dhar pillar in its completed condition would be the biggest iron pillar in the whole world.

THE IRON PILLAR ON MOUNT ABU.

On Mount Abu, situated in the lower part of Rajputana, stands the temple Achaleswar, built in A.D. 1412 (sambat 1468). An iron

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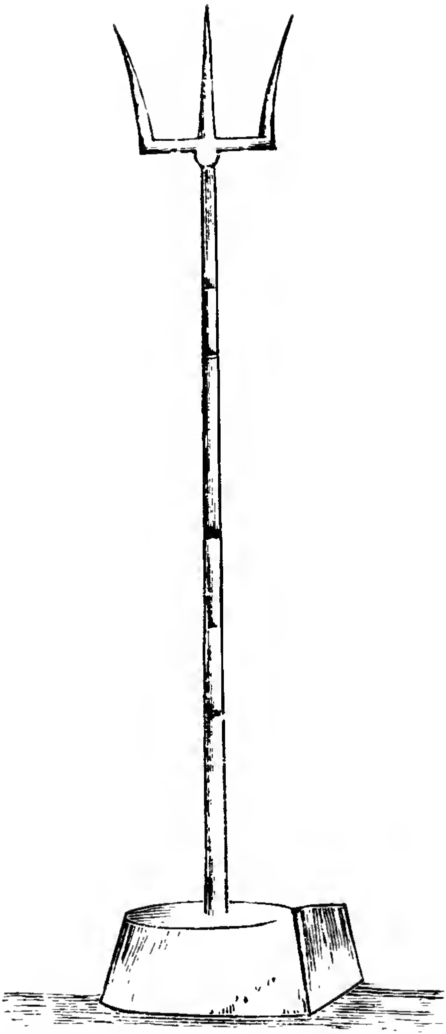
[1] Fergusson, ibid.

[2] This Raja Bhoja was a king of Mālava (1010–1053 A.D.) called Bhoja Paramār He is a different personage from the other king of the same name (Vincent Smith's Early History of India, second edition, p. 365). If the pillar was really erected by Raja Bhoja the date of its erection would be eleventh century.



Iron Pillar on Mount Abu

(Drawn on an enlarged scale from a sketch of the pillar given in Plate XXXI, Annual Report, Archaeological Survey of India, 1902-3, page 206.)

pillar—the third of its kind—12 feet 9 inches high is situated in the courtyard of the temple with a Saiva trisul or trident on its top. It is stated that just before the death of the Pathan Emperor Alauddin, when rebellion broke out iu all parts of India, the Hindus defeated the Mussalmans and built this pillar as a mark of victory with the molten implements of war left by the flying Mussalmans.[1] The iron of the pillar has not yet been under examination, but I have little hesitation in concluding that the pillar is made of wrought iron in a similar manner as the Delhi and Dhar pillars. The iron of this pillar as well as that of the Delhi pillar were probably obtained from Rajputana itself, as numerous hillocks of iron slag exist near Khetri and other places in Rajputana, showing that iron was smelted there in large quantities from ancient times.

IRON IN THE GATES OF SOMNATH.

Dr. P. C. Ray in his History of Hindu Chemistry has written "The wrought-iron pillar close to the Kutub near Delhi, which weighs ten tons[2] and is some 1500 years old; the huge iron girders at Puri; the ornamental gates of Somnath, and the 24 feet wrought-iron gun at Nurvar are monuments of a bye-gone art and bear silent but eloquent testimony to the marvellous metallurgical skill attained by the Hindus." The Delhi pillar and the Puri girders certainly bear 'silent but eloquent testimony' to the metallurgical skill of the Hindus, and the wrought-iron gun also does so in a certain sense, as though guns were introduced by the Mahomedans into India after the Moghul conquest, the workers in iron as will be shown later on, were mostly Hindus. As regards the ornamental gates of the celebrated temple of Somnath carried away by Mahmood to Ghazni in 1026, the iron in the gates however cannot be regarded as a specimen of Indian iron. Fergusson says that the original gates of Somnath were made of sandal-wood and microscopic examination of the wood of the present Somnath gates, triumphantly brought back by Lord Ellenborough at the conclusion of the second Afghan War and now deposited in the Agra fort, reveals the fact that they are made of Deodar wood. Prof.

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[1] C. H. Cousens, Annual Report, Archaeological Survey of India, 1902–03.

[2] This is a mistake. The pillar weighs about 6 tons.

Simpson, the well-known artist, says "Rude repairs are done in the gates with scraps of wood and iron."[1] As suspicion has been thrown by authoritative writers on the authenticity of the claims of the gates deposited in the Agra fort to be identical with the gates of Somnath, and even if assuming that the gates are authentic, the pieces of iron used in making rude repairs in the gates cannot be regarded as specimens of ancient Indian iron. The same mistake of regarding the iron in the Somnath (Somnali) gates as a specimen of Indian iron has been made by Dr. Kumarswamy in his work on Ceylonese Art and by Sir Robert Hadfield who has quoted his remarks.[2]

IRON GUNS AND CANNON.

It has already been pointed out that a form of iron fire-weapon was known even in Vedic times (p. 5). It is also undoubted that some sort of fire-weapon was known during the epic age as we find frequent mention of 'Satagni' (killer of hundreds), 'āgneya-astra' (fire-weapon), and 'nālika-astra' (tube-weapon) in the epics and ancient Sanskrit literature. But it seems that guns and cannon and the use of gunpowder were unknown in India before the Moghul conquest. Guns were first employed by Babar in the first battle of Panipat in 1526 and were introduced in Southern India by the Portuguese. Guns and cannon, as well as formula for the manufacture of gunpowder, have been given in a Sanskrit work entitled *Sukraniti*, a compilation evidently of the sixteenth century. In *Sukraniti*, *khudra-nālika* stands for small guns or matchlocks and *brihaṇnālika* for big guns or cannon. The matchlock was 2½ cubits long with a longitudinal bore of the thickness of the middle finger and provided with two raised points in order to take aim.

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[1] Keene's 'Agra,' Appendix.

[2] *Iron in Allauddin's gates in Delhi:* While visiting Northern India in 1909 I happened to observe that inside a broken place in the celebrated Allauddin's Daroja near the Kutub Minar at Delhi something like iron was visible The broken place had a diameter of 2 or 3 inches and it appeared that the huge stone gates had in the inside iron plates in order to give them more strength. I mention this fact here as it may attract the notice of the Archaeological Survey of India who may examine the gates more thoroughly. The gates were constructed by the celebrated Pathan Emperor Allauddin Khilliji in 1307 or 1315 (Henry Hardy Cole's Architecture of Ancient Delhi). If my suspicion about this iron turns out to be correct, it would be a specimen of iron of the times of the Pathan rulers of Delhi.

The gunpowder was ignited by means of a fuse, the fire being originated by percussion of powdered stone struck with a hammer. The matchlocks had wooden handles and were used by infantry and cavalry. The big guns were carried in carriages, had no wooden handles, and their range depended on the thickness of the metal-plate and bore, their length and size of balls.[1] These passages have misled many people, including the late Mr. Ramdas Sen, into believing that guns and gunpowder were known to the ancient Hindus. Dr. Rajendra Lal Mitra and Dr. P. C. Ray on the other hand regard them to be either spurious or in the nature of later interpolations.[2]

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[1] The original passages in *Sukraniti* are given below :—

नालिकं द्विविधं ज्ञेयं बृहत्क्षुद्रविभेदतः ।
तिर्य्यगूर्द्ध्वच्छिद्रमूलं नालं पञ्चवितस्तिकम् ॥
मूलाग्रयोर्लक्ष्यभेदि तिलबिन्दुयुतं सदा ।
यन्त्राघाताग्निकृद्ग्रावचूर्णधृक्कर्णमूलकम् ॥
सुकाष्ठोपाङ्गबुध्नञ्च मध्याङ्गुलबिलान्तरम् ।
स्वान्तेऽग्निचूर्णसन्धातृशलाकासंयतं दृढम् ॥
लघुनालकमप्येतत् प्रधार्य्यं पत्तिसादिभिः ।
यथा यथा तु त्वक्सारं यथा स्थूलबिलान्तरम् ॥
यथादीर्घं बृहद्गोलं दूरभेदि तथा तथा ।
मूलकीलभ्रमाल्लक्ष्य समसन्धानभाजि यत् ॥
बृहन्नालीकसंज्ञं तत् काष्ठबुध्नविवर्जितम् ।
प्रवाह्यं शकटाद्यैस्तु सुयुक्तं विजयप्रदम् ॥

शुक्रनीति, IV, 7.

Formulæ for the manufacture of gunpowder (one formula being 5 parts of nitre, 1 part of sulphur and 1 part of charcoal) and description of shots and balls are also given.

[2] I am afraid it cannot well be contended that the portions of Chapter IV which give accounts of gun cannon and gunpowder were mere later intorpolations, as guns and cannon have been mentioned in many places *throughout the work*, suggesting the idea tbat the work was written, at any rate rewritten, after the introduction of guns and gunpowder in India. Besides mentioning guns and gunpowder *Sukraniti* mentions *Yavanas* or *Mlechchas* living in ' North and Western ' India, evidently referring to the Mussalmans. That the work could not have been written before the fourteenth century is borne out by the fact that it mentions ' Zinc ' as one of the seven metals, while as a matter of fact only six metals were recognized

Tavernier, however, gives the credit of discovering guns and gunpowder to the Ahoms of Assam. In narrating the result of Mir Jumla's expedition to Assam in 1663 Tavernier wrote, "It is thought that these (the Ahoms) were the people that formerly invented gunpowder: which spread itself from Assam to Pegu and from Pegu to China, whence the invention has been attributed to the Chinese However, certain it is that Mirgimola brought from thence several pieces of cannon which were all iron guns, and store of excellent powder, both made in the country. The powder is round and small like ours and of excellent quality."[1] Mr. Gait in his *History of Assam*, however, writes that there was no history or tradition in Assam to support Tavernier's assertion. Mr. Gait further writes, "The use of fire-arms by the Ahoms dates from the close of this war (war with the Mahomedans under Turbak and Hosain Khan in 1533, in which the Mahomedans were defeated and a great number of cannon and matchlocks were captured by the Ahoms). Up to this time their weapons had consisted of swords, spears and bows and arrows."[2] It is possible that some of these captured guns were recaptured by Mir Jumla from the Ahoms during his invasion of Assam later on, and hence Tavernier's assertion.

We would now describe some remarkable specimens of very big iron guns of the Moghul times still existing in different parts of India. Guns were cast in brass or made by welding pieces or rings of wrought iron. Laterly guns were made from cast iron as well, but it is difficult to say precisely when iron guns were first cast. It seems that cast-iron guns were introduced into India by the Europeans in the eighteenth century.

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up to the thirteenth century and zinc only found a place amongst the metals in *Madanpāla-Nirghantu*, and other alchemical works of the fourteenth century and later. I am afraid Prof Benoy Kumar Sarkar in his "Hindu Sociology" has laboured in vain to explain away the arguments adduced above, which jointly show that the work could not have existed in its present form before the sixteenth century. Moreover Prof. Sarkar has conveniently forgotten to explain the frequent mention of guns and cannon in his eagerness to establish the antiquity of the "Sukra cycle of philosophers."

[1] Tavernier, *Travels in India*, 1678, Pt. II, Bk. III, p. 187 (quoted by Mr. Gait in his *History of Assam*).

[2] Gait, *History of Assam*, p. 92.

Bengal guns: There are many big iron guns of the Moghul times in many parts of Bengal, notably in Dacca, Murshidābād, Bishnupur, Bhāgulpur and other places. Rennel in his celebrated "Memoir of a map of Hindoostan" has described a gigantic wrought-iron gun he found at Dacca in the eighteenth century. He writes: "There are the remains of a very strong fortress in it; and within these few years there was near it a cannon of extraordinary weight and dimensions: but it has since fallen into the river, together with the bank on which it rested."[1] Rennel took the measurements of the gun very carefully, which are given below:—

Whole length	22 feet	10½	inches.
Diameter at the breech ..	3 ,,	3	,,
,, 4 feet from the muzzle	2 ,,	10	,,
,, of the muzzle	2 ,,	2⅛	,,
,, of the bore	1 ,,	3⅛	,,

He says, "it was made of hammered iron; it being an immense tube formed of 14 bars, with rings of 2 or 3 inches wide driven over them, and hammered down into a smooth surface, so that its appearance was equal to that of the best executed piece of brass ordnance, although its proportions were faulty. The gun contained 234,413 cubic inches of wrought iron and consequently weighed 64,814 pounds avoirdupois, or about the weight of eleven 32-pounders. Weight of an iron shot from the gun, 465 pounds." Local tradition names the gun as *Kāley Khān*, a gun of that name being mentioned by the Venetian traveller Manucci in the list of big cannon possessed by the great Moghul in the seventeeth century.[2]

A smaller iron gun still exists at Dacca which was constructed at the same time as the bigger one. Mr. H. E. Stapleton took its measurements, the gun being 11 feet long and the diameter of its mouth 1 foot 7½ inches.

The great iron gun at Murshidābād, called Jāhānkoshā (conqueror of the world), 17 feet 6 inches in length and with a circumference of 5 feet 3 inches, is of great historical importance owing

[1] Rennel's "*Memoir of a Map of Hindoostan*," third edition, 1793, p 61.

[2] Manucci, History of the Moghuls (Irvine's translation), 1653–1708, Vol. II, p. 365.

to the existence of nine inscribed brass plates on it. From the inscription it is ascertained that this gun was constructed in 1047 Hijira, Jamadinssani (October, 1637), during the reign of Emperor Shājāhān (the then Subādār of Bengal being Islām Khān) at Jahāngirnagar (Dacca) by chief mechanic Janārdan under the supervision of Darogā Sher Mahammad and Inspector Harabullava Dās.[1]

Another inscribed big gun was presented in 1891 by Captain Petley, being dug up at False Point, to the Asiatic Society of Bengal, in whose rooms it has been preserved. Mr. C. R. Wilson from the inscription reads the date as [1] 584 Saka era or 1622 A.D., and says: "The gun was captured from Aurungzebe's General, Mir Jumla in 1662, by Svargadev Jayadhvaja Sinha, the then reigning Ahom Prince of Assam. From Assam it was carried away to Burma. It was taken by the English in the first Burmese War and on the completion of the light-house at False Point in 1838, it seems to have been removed from the old fort at Cuttack and buried in the ground near the light-house to hold a flag staff."[2] This gun was also manufactured in the same way as the Dacca guns from wrought iron. Mahamahopadhaya H. P Shastri, who examined the gun, writes: "The gun is made in the old-fashioned method of welding together a number of large iron rings, three inches thick, with an opening in the middle with a diameter of three inches."[3]

Besides the above there are several old iron guns at Bishnupur in Bengal and several inscribed Assam guns of the sixteenth and seventeenth centuries have been described by Mr. Rakhaldas Banerji.[4] On one of these Assam guns there is a Persian inscription "taiyār shud" meaning "was manufactured" in contrast with "rekhta shud" or "was cast," the latter inscription occurring, according to Prof. Jadu Nath Sircar, on many other guns,

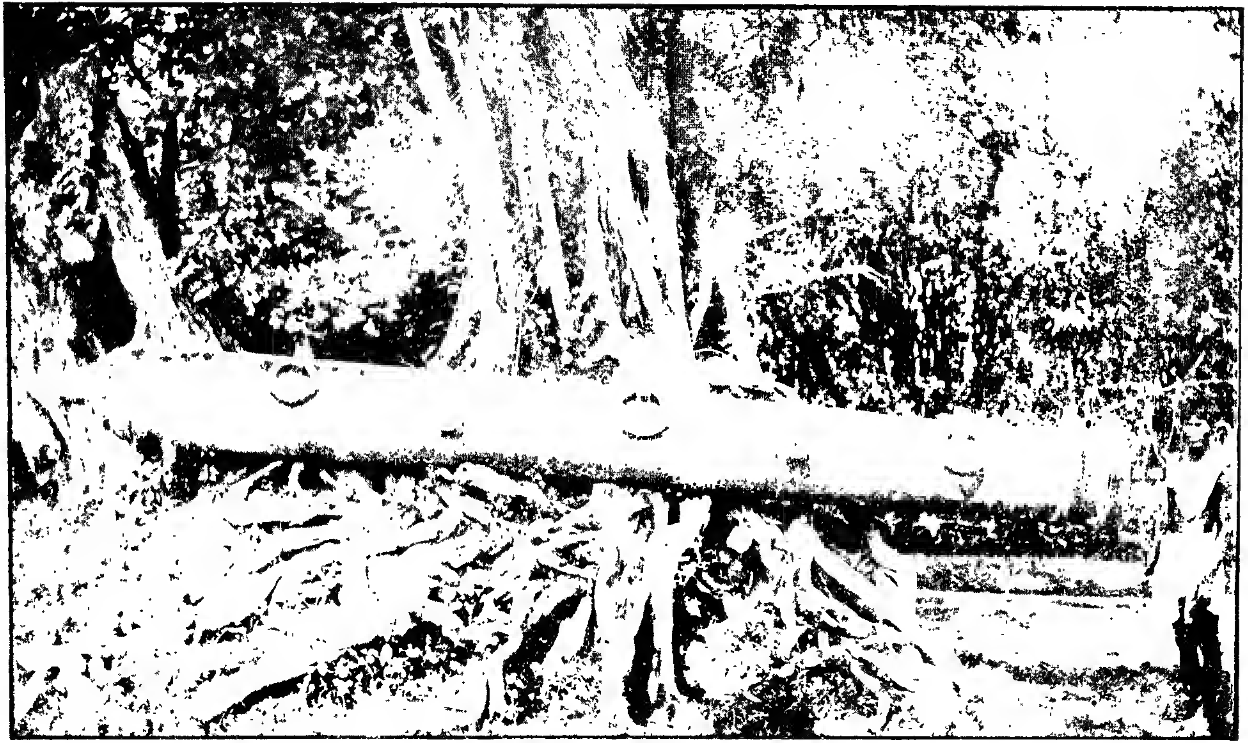
[1] Kaliprasanna Banerji, *History of Bengal* (in Bengalee), p. 521.

[2] C. R. Wilson's "Catalogue of Antiquities in the Asiatic Society of Bengal," p. 2. Gait (Report on Historical Research in Assam, 1896, p. 29) makes the date A.D. 1658, while H. P. Shastri makes it A.D. 1525, based evidently on a wrong reading of the inscription.

[3] Proceedings, Asiatic Society of Bengal, 1890, 167.

[4] Journal, Asiatic Society of Bengal, 1909 and 1911.

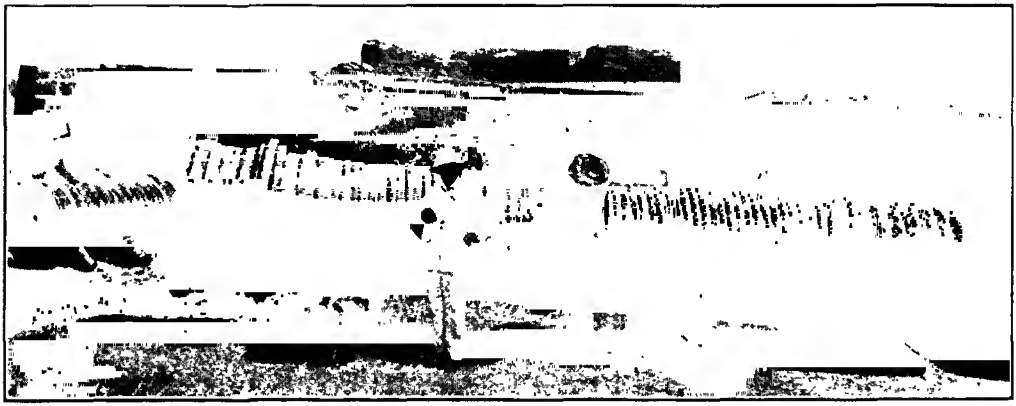
PLATE V.



Iron Gun at Murshidabad

(Photograph by Johnston and Hoffmann, Calcutta.)

PLATE VIII



The Landa Kesab Gun at Bijapur.

(The Empress, May, 1913, No. 2, page 12.)

presumably made of brass.[1] This inscription unmistakably shows that the Assam guns were really made from wrought iron.

From the description of the guns in Bengal given above two facts come out very clearly:—

(*a*) That in the sixteenth and seventeenth centuries guns were manufactured in India by welding pieces or rings of wrought iron. The manufacture of a big iron gun, 21 feet long, by hammering and welding wrought iron, as described by Rennel, in such a manner that "its appearance was equal to that of the best executed piece of brass ordnance" unmistakably shows that Indians lost none of their old marvellous metallurgical skill which could produce at one time a Delhi or a Dhar pillar. This fact also shows that the production of wrought iron in India during the sixteenth and seventeenth centuries still continued to be on a considerable scale.

(*b*) From the inscription on the Murshidābād gun which was manufactured at Dacca we learn that the gun was constructed by a Hindu head-mechanic. That opens up an important subject. It seems that the Dacca, Murshidābād and Bishnupur guns were all manufactured by Hindu mechanics and metallurgists under the orders of the Mahomedan rulers. Mr. Lister[2] in the Presidential address to the Staffordshire Iron and Steel Institute says: ' It was believed that the Mahomedans never made iron although acquainted with the higher arts in its use." It appears that the Hindus were skilled workers in iron in all ages and their remarkable skill was utilized by the Mahomedan rulers in the manufacture of wrought-iron guns which must be really regarded as specimens of Hindu art.

Bijāpur guns: We have no space here to touch upon the smaller guns and would conclude with the description of several gigantic guns of the sixteenth and seventeenth centuries in other parts of India. There is a big 24 feet wrought-iron gun at Nurvar. On the south wall of the city of Bijāpur there is still to be seen the celebrated Landa Kesab gun. It is also made of circular iron rings shrunk

[1] I enquired from Prof. Jadunath Sircar if he had met with the Persian inscription "was cast" on any iron gun of the Moghul times. In reply Prof Sircar informs me that the Moghul iron guns he has seen in Northern and Southern India were made of wrought iron.

[2] Iron and Coal Trades Review, Vol LXXXIII, p. 561.

on longitudinal iron bars and then welded together. Aurungzebe is credited to have removed the original points on which it turned in order to make it practically useless. It is 21 feet 7 inches long, diameter at the breech is 4 feet 4 inches, calibre 1 foot 7 inches, length of bore 18 feet 7 inches and the estimated weight 47 tons.

The long gun, named the "farflier," which is said to have been raised on the huge tower known as the Haider Burj at Bijāpur by means of an inclined plane over a mile long, should be of interest in this connection. This gun, too, was constructed of iron bars of square section and laid longitudinally along the bore, over which rings were slipped, one at a time, while the last was red-hot. As they cooled they shrank and bound the iron bars together. The gun near the breech was strengthened by the addition of a second layer. It is 30 feet 8 inches long and has a bore 1 foot in diameter.

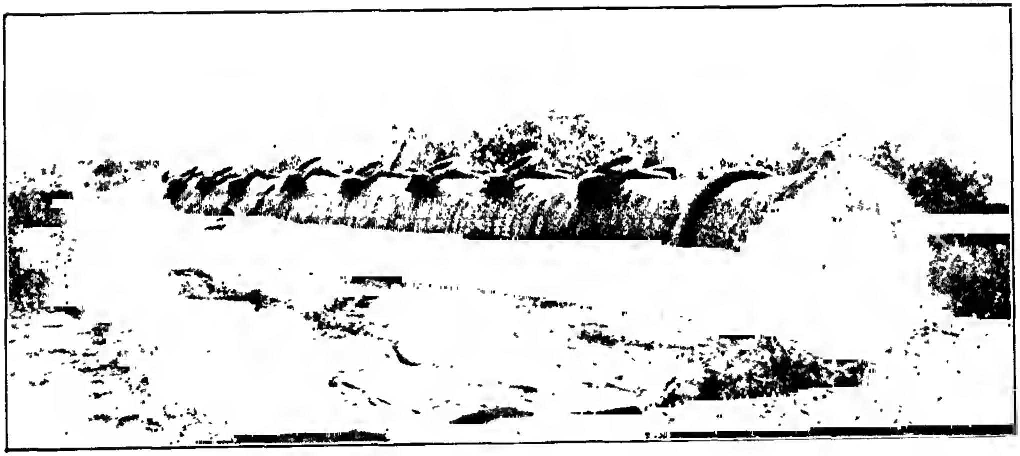
The long gun at Gulburga seems to have been made in a similar way, but it is worthy of notice that there is double row of iron rings, ten on each side. It was doubtless by means of these the gun was conveyed from point to point, for there is no evidence of any pivot or other arrangement by which it could be moved.[1]

We have given here photographs of three guns, viz. the Murshidābād gun, the Landa Kesab gun and the Gulbarga gun. It is unnecessary for our purpose to multiply the number of such photographs.

It is not necessary here to refer to iron 'bundooks' or matchlocks except in a general manner. The *Ayeen Akbari*, which says that excepting Room (ancient Turkey) no kingdom could compare with the Indian Empire under the Moghuls in the number and variety of its ordnance, describes the details of manufacturing matchlocks from wrought iron which would be of some interest. "Bundooks are now made in such a manner that when filled with powder up to muzzle, there is no fear of their bursting. Formerly they never were of more than four folds of iron, and sometimes only of one, joined together by the two extremities of the breadth, and which were very dangerous. His Majesty

[1] The description of the Bijapur guns has been taken from an illustrated article in the "Empress," May, No. 2, 1904, pp. 12 and 13.

PLATE IX



The Iron Gun at Gulburga.

(The Empress, May, 1913, No. 2, page 12)

(Emperor Akbar), after having the iron flattened, has it rolled up like a scroll of paper, but slantingly, and every fold is passed through the fire. There is also the following method: solid pieces of iron are properly tempered and then bored with an iron borer; and three or four of these are joined together to form a bundook In preparing the iron for bundooks half is lost in the fire." [1]

Innumerable matchlocks of the Moghul times can be seen in the treasure-houses of most of Native princes and influential Zemindars of India.

From the ancient specimens of Indian iron described above the reader will easily see that the metallurgical skill of the ancient Hindus is writ large on the wonderful series of iron articles of all ages from prehistoric times down to the seventeenth century. The story of iron manufacture in ancient India is really wonderful and perhaps unique in the annals of metallurgy in the whole world.

We give below a summary of the specimens of ancient Indian iron described above :—

Iron swords, daggers, etc., at Tinnevelly ..	.. Prehistoric.
Iron slag at Bodh-Gaya	.. Third century B.C.
Iron spear-head and nails at Piprhāwā ..	.. First or second century A D.
Iron clamps at Bodh-Gaya	.. Fourth century A.D. to sixth century A.D.
Iron beams at Bhubaneswar, Puri and Konarak	.. Sixth century A.D. to thirteenth century A.D.
Iron pillar at Delhi	.. Fifth century A.D.
Iron pillar at Dhar	.. Twelfth century A.D.
Iron pillar on Mount Abu	.. Fifteenth century A.D.
Iron guns and cannon	.. Sixteenth and seventeenth centuries A.D.
Cast iron at Rungpur (to be described later on)	.. Eighth to tenth century A.D.

We bring to a close our history of ancient Indian iron speci-

[1] Ayeen Akbari, Gladwin's Translation, Vol. I, p. 111.

mens with the seventeenth century, as from the eighteenth century European nations began to assert more and more political supremacy over India, and European enterprise and commerce began gradually to supplant the indigenous industries. The scientific spirit of enquiry in India was gradually on the wane from the twelfth or thirteenth century, if not earlier, and by the seventeenth century was almost completely decadent, though old processes continued in the absence of foreign competition. On the other hand, after the gloom and torpor of the Middle Ages, Europe began to pulsate by the seventeenth century with a new spirit of scientific enquiry which increased in volume and intensity every year. This spirit began to permeate and influence manufacture and commerce in an ever-increasing measure, and within a century or two European manufacture almost completely supplanted Indian industries of almost every description. So far as the iron industry is concerned, the old processes continued, though on an infinitely smaller scale, and in fact still continue in many places even now, being relegated to the lowest and illiterate classes, until, as at present, iron of European manufacture completely dominates the Indian market.

CHAPTER IV.

Matters of Chemical Interest relating to Indian Iron.

ANALYSIS OF INDIAN IRON.

All the specimens of iron described before have not been analysed. The Archaeological Department would do well to have them analysed and thus help chemists to properly understand the subject of metallurgy of iron in ancient India.

A complete analysis of the iron of the Delhi pillar by Sir Robert Hadfield has been given on page 19, and the analysis of a specimen of Konarak iron by the author on page 26.

Sir Robert Hadfield has published analyses of a number of specimens of Ceylonese iron of the fifth century A.D. in the Proceedings of the Royal Society and Journal of the Iron and Steel Institute.[1] As Ceylon might be regarded to be a part of Greater India in ancient times, analyses of Ceylon iron of the fifth century would be of interest in connection with Indian iron.[2] We give below the analyses of an iron nail, a chisel and a bill-hook.

Iron nail :—

Specific gravity 7·69.

	Per cent.
Carbon	Traces.
Silicon	·11
Sulphur	Nil.
Phosphorus	·32
Manganese	Nil.

1 Hadfield, *Journal of the Iron and Steel Institute*, 1912, pp. 163—168

2 In the fifth century B.C. Vijaya, the son of Sinhabahu, a King of Magadha, is said to have been exiled by his father for many acts of fraud and violence, and this Prince came by sea to Ceylon, conquered the island and founded a dynasty of kings. Ceylon was converted into Buddhism in the third century B.C. by the missionaries sent by King Asoka under the leadership of his monk brother Mahendra who spent the rest of his life there.

Iron chisel :—

Specific gravity 7·69.

Carbon	Traces.
Silicon	·12
Sulphur	·003
Phosphorus	·28
Manganese	Nil.
Iron	99·3

Iron bill-hook :—

Specific gravity 7·5.

Carbon	Traces
Silicon	·26
Suphur	·022
Phosphorus	·34
Manganese	Traces.

It will be noted that the composition of Ceylonese iron is exactly analogous to that of the iron of the Delhi pillar and Orissan beams. It is very likely that Indian iron was exported to Ceylon in ancient times.

An analysis of a specimen of cast iron discovered in the ruins of Bhaba Chandra Pāt near Rungpur has been given in the paragraph dealing with cast iron (p. 78).

TENSILE STRENGTH OF INDIAN IRON.

Mr. Monomohon Ganguli of the Public Works Department, whose recent work on " Orissa and her Remains " is an excellent publication on the subject, sent a very small piece of wrought iron from an iron beam at Bhubaneswar to the Civil Engineering College, Sibpur, where Prof. Sarat Kumar Dutt tested its tensile strength in the Testing laboratory of the College. Prof. Dutt got a small piece made of it of cross-section ·27″ × ·415″ and after testing it observed " this broke at 1·6 tons. The breaking strength accordingly comes to about 14·3 tons per square inch . . . . unfortunately the sample was not without flaws and the test piece broke at one of these flaws . . . . . If it had been possible to obtain a decent sample of the iron, I believe, a strength of 20 tons per square inch could be easily attained," the accepted tensile stress of pure wrought iron

having an average of 25 tons per square inch. "The assurance of Prof. Dutt that a decent sample of this iron could easily show a strength of 20 tons per square inch reflects great credit on the Orissan matallurgists of a bye-gone age, for the average tensile strength of wrought iron was 23 tons per square inch in England only 36 years ago."[1]

Prof. Dutt's experiments are, however, not very conclusive. Fortunately we have before ourselves the experiments of Sir Robert Hadfield on the tensile strength of Ceylonese iron, which are quite conclusive. Sir Robert found that the breaking load in the case of the iron nail was 21 tons per square inch, the chisel 26 tons, and bill-hook as high as 29 tons per square inch, being higher than the figure for wrought iron. This no doubt is owing to the considerable percentage of phosphorus present, which stiffens or hardens iron.

Hadfield has also determined the Fremont shock test, the Brinell ball test for hardness, as well as scleroscope hardness of the specimens of Ceylonese iron. His conclusions are summarized thus: "The Fremont shock tests show fair results on the specimen taken from the chisel, namely 17 kilogrammes, with 85° bend. The other specimens, however, show much lower figures, namely the nail (1 kilogramme by only 1° bend) and the bill-hook (7 kilogrammes by 35° bend). The hardness by the Brinell method varied from 117 to 166, one result from the nail showing 209; but this is abnormal, and cannot be accepted as representative. The scleroscope tests varied from 25 to 44, and as a comparison it may be mentioned that water-quenched carbon steel by this latter method shows 100 and ordinary wrought iron about 20."

MICROGRAPHIC EXAMINATION OF ANCIENT CEYLON IRON.

The author is not aware of my micrographic examination of the iron of the Delhi pillar or any other specimen of ancient Indian iron. The results of micrographic examination of the three specimens of Ceylon iron by Sir Robert Hadfield will prove interesting. For photographs of micro-sections the reader is referred to Hadfield's paper. We give below only the results obtained by him with res-

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[1] Monomohon Ganguli's "Orissa and her Remains", p. 263.

pect to the iron chisel, nail and bill-hook, analyses of which have already been given.

Iron chisel: The transverse section shows that the chisel has been carburised, the section showing the carburised areas to be on two sides. The carburisation varies on two faces from saturation point (·9 per cent) to about ·2 per cent certain on the outside edge and the depth of carburisation from the edge inwards is also shown to be variable. The presence of matensite and hardenite suggest the important information that the chisel has been quenched. Further micro-sections were prepared from the specimen cut from the nose of the chisel. These photo-micrographs also appear to carry evidence that the chisel has been quenched for the structure is in parts martensitic. Troostite is certainly also present, which is probably the result of tempering by the long lapse of time. Hadfield believes that for the first time there has been put on record evidence of the art of cementation having been known 1500 to 2000 years ago, as shown by these specimens; probably, therefore, such knowledge could be traced back still further.

Iron nail: The microstructures indicate a remarkable conglomeration. One plate shows a weld running diagonally across the section, and along the edges of the weld there are carburised areas. Another notable point is that on one side of the weld the slag shows the effect of the forging, whereas on the other side there is no such sign. The specimen is covered with slip bands and has evidently undergone severe hammering, probably in its use as a nail. The carbon in the carburised areas exists as granular pearlite.

Iron bill-hook: The report of the microstructure of the specimen shows that it contains a large amount of slag and appears to represent what would be now termed a somewhat low quality of wrought iron. There seems to be practically no carbon present and therefore no evidence of treatment other than forging can be obtained.

VARIETIES OF INDIAN IRON.

At present three principal varieties of iron are recognized according to the amount of carbon contained in them, viz. wrought iron, steel and cast iron. Each of these principal varieties is again sub-divided into other varieties according to the difference in their composition and properties. In ancient India also various kinds

of iron were known and recognized by their different properties. The principal varieties were 'munda' (cast iron), 'tikshna' (sharp iron or steel) and 'kānta' (wrought iron).

The Sanskrit work *Yuktikalpataru*, a manuscript of the eleventh century, which has not yet been published, describes the relative goodness of various qualities of iron thus: "*Crouncha* iron is twice better than *shāmānya* (ordinary) iron, *kālinga* (Orissan) iron eight times better than *crouncha* iron, *bhadra* iron one hundred times better than *kālinga* iron, *bajra* iron thousand times better than *bhadra*, *pāndi* iron again hundred times better than *bajra*, *niranga* ten times better than *pāndi* and *kāntha* iron million times better than *niranga* iron."[1]

Rasaratna-Samuchchaya, a work of the thirteenth century, mentions three kinds of iron, viz. *munda* (cast iron), *tikshna* (steel) and *kānta* (wrought iron).

Munda again is of three varieties, viz. '*mridu*,' *kuntha* and *kadāra*.

That which easily melts, does not break and is glossy is *mridu*; that which expands with difficulty when struck with a hammer is known as *kuntha*; that which breaks when struck with a hammer and has a black fracture is *kadāra*.

Tikshna: There are six varieties of it, viz. *khara*, *sāra*, *hrinnāla*, *tārābatta*, *bājira*, and *kālalauha* (black metal). One variety is rough and free from hair-like lines and has a quicksilver-like fracture and breaks when bent. Another variety breaks with difficulty and presents a sharp edge.

Kānta: There are five kinds of it, viz. *bhrāmaka*, *chumbaka*,

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[1] सामान्याद्द्विगुणं क्रौञ्चं कालिङ्गाष्टगुणस्ततः ।
कलेः शतगुणं भद्रं भद्राद्वज्रं सहस्रधा ॥
वज्रात् शतगुणं पाण्डि निरङ्गं दशभिर्गुणैः ।
ततः कोटिसहस्रैर्वा कान्तलौहं महागुणं ॥ युक्तिकल्पतरु ।

This passage has been quoted in *Rasendrarshār-samgraha*, a Tāntrik work of the thirteenth or fourteenth century, thus showing that *Yuktikalpataru* must have been written two or three centuries before, so that its date would be circa eleventh century.

The mention of *kalinga* iron in the passage quoted above shows that Orissa was always famous for her iron, and in fact even the Tata Iron and Steel Company get their supply of iron ores from the state of Maurbhanja in Orissa.

karshaka, *drāvaka* and *romakāntā*. It possesses one, two, three, four and five faces and often many faces and is of yellow, black and red colour respectively. The variety which makes all kinds of iron move about is called *bhrāmaka*, that which kisses iron is called *chumbaka*, that which attracts iron is called *karshaka*, that which at once melts the iron is called *drāvaka* (lit. a solvent) and the fifth kind is that which, when broken, shoots forth hair-like filaments.[1]

From the description of the different varieties of iron it is quite evident that *munda* really means 'cast-iron' as its different varieties easily melt, break when struck with a hammer and have black fracture. The six varieties of *tikshna* are evidently varieties of steel presenting a 'sharp edge,' 'breaking when bent' or 'breaking with difficulty.' The five varieties of *kānta* are not easy to

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[1] अथायः,—
मुण्डं तीक्ष्णं च कान्तं च त्रिप्रकारमयः स्मृतम् । 70
अथ मुण्डम्,—
मृदु कुण्ठं कडारं च त्रिविधं मुण्डमुच्यते ।
द्रुतद्रावमविस्फोटं चिक्कणं मृदु तच्छुभम् ॥
हतं यत् प्रसरेद्दुःखात् तत्कुण्ठं मध्यमं स्मृतम् ।
यद्धतं भज्यते भङ्गे कृष्णं स्यात् तत् कडारकम् ॥ 71—72
अथ तीक्ष्णम्'—
खरं सारं च हृन्नालं तारावट्टं च वाजिरम् ।
काललोहाभिधानं च षड्विधं तीक्ष्णमुच्यते ॥ 75
पदषं पामरोमुक्तं भङ्गे पारदवच्छवि ।
नमने भङ्गुरं यत् तत् खरलोहमुदाहृतम् ॥ 76
वेमभं गुरुधारं यत् सारलोहं तदीरितम् । 77
अथ कान्तम्,—
भ्रामकं चुम्बकं चैव कर्षकं द्रावकं तथा ।
एवं चतुर्विधं कान्तं रोमकान्तं च पञ्चमम् ॥ 84
एकद्वित्रिचतुःपञ्च सर्व्वतो मुखमेव यत् ।
पीतं कृष्णं तथा रक्तं त्रिवर्णं स्यात् पृथक् पृथक् ॥ 85
भ्रामयेल्लोहजातं तु तत् कान्तं भ्रामकं मतम् ॥ 88
चुम्बयेच्चुम्बकं कान्तं कर्षयेत् कर्षकं तथा .
साक्षाद् यद् द्रावयेल्लोहं तत्कान्तं द्रावकं भवेत् ॥ 89
तद् रोमकान्तं स्फुटिताद् यतो रोमोद्गमो भवेत् । 90
रसरत्नसमुच्चय (Poona edition), fifth chapter. pp. 26 and 27.

The English translation of the passages is taken (with alterations) from P. C. Ray's History of Hindn Chemistry, Vol. I.

identify. As *kānta* iron has been described the best of all varieties of iron in many books, it certainly refers to wrought iron, but in the passage quoted the varieties of *kānta* iron include magnetised iron also as they 'kiss' or 'attract' iron.

In *Rasendrashār-samgraha* we have got a passage in which the same three kinds of iron are mentioned, viz. *munda*, *tikshna* and *kānta*. In this passage also it is stated that "*munda* is ten times better than iron rust, *tikshna* hundred times better than *munda*, and *kānta* million times better than *tikshna* iron." [1]

THEORY OF FORGING IRON BEAMS AND PILLARS.

It has already been stated that Dr. Percy, Dr. Murray and Sir Robert Hadfield found the Delhi pillar to be made of wrought iron. The iron beams of Orissa have also been found to be made of the same species of iron. These beams and pillars must then have been constructed by forging large quantities of wrought iron. The question now is—have these beams and pillars been forged as single columns or that short pieces of wrought iron have been forged and then welded? Experts are unanimously of opinion that such an enormous mass of iron as the Delhi pillar can even in these days of steam-rollers and hammers be with very grea difficulty forged. The conclusion therefore naturally arises that these beams and pillars must have been constructed by welding short pieces of wrought iron and not as entire columns. Direct evidence on this point is forthcoming, though it still reflects the greatest credit on the old Hindu metallurgists who could have successfully carried on the welding operations so very skilfully as to be scarcely perceptible.

Writing about the beams in Konarak, H. G. Graves points out: [2] "One beam, which is now lying on the portico, has evidently been partially exposed for a long period to the sandy winds, for it is worn down at least an inch in depth, enabling the defective structure to be seen. This particular beam and the fractured ends show very clearly that the method of manufacture

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[1] "किट्टाद्दशगुणं मुण्डं मुण्डात्तीक्ष्णं शताधिकम् ।
तीक्ष्णाल्लक्षगुणं कान्तं" — रसेन्द्रसारसंग्रह ।

[2] Journal of the Iron and Steel Institute, 1912, No. 1, Vol. 85, p. 196.

was by welding up small blooms, generally about 3 or 4 lbs. in weight. The blooms are commonly 2 by 1 inch in section, but occasionally 2 by 2 inches or 1 by 1 inch, and a common length is about 6 inches. In a few cases the blooms may have been larger or the welding was done more effectively. The rough sketches appended to this paper show with fair accuracy the relative sizes and disposition of the blooms in several beams. Many of the broken ends show the existence of irregular and sometimes uniform cavities. It is possible to thrust a stick down some of them to a depth of 7 or 8 feet, and the sand-blasted specimen shows a cavity nearly the whole length of the beam. From these hollows, bits of cinder can be raked out.'' The blooms were probably welded together into short bars which were then in turn welded into big beams. Mr. Graves say that externally the beams are well finished though the cracks and lines show where joints were (see plate No. 4).

As regards the Delhi pillar, the forging in this case is much more perfect than that of the Orissan beams and hence difficult to detect. The Committee of the Iron and Steel Institute in 1872, however, made some special enquiries with regard to this pillar.[1] Lieutenant Spratt of the Royal Engineers, then stationed at Delhi, came to the conclusion after enquiry that "the iron of which the pillar is made seems to have been originally in blooms of about 80 lbs. weight each.'' Even as early as 1858 Mr. Charles Wood of Middlesburgh, who was in India at the time of the Mutiny, stated that he believed that the pillar was of wrought iron and that it had been made by welding small pieces into the end of a shaft or bar. In 1871 Mr. Robert Mallet had stated: "We are thus obliged to consider that this pillar is not a casting but a huge forging in .... wrought iron,'' while shortly afterwards Mr. G. M. Fraser contributed a long letter to the *Engineer*, Vol. xxxiii, pp. 19, 20, in which the fact is clearly expreseed that the pillar was made of malleable iron and produced by welding together successive lumps or *mootees* of wrought iron which had been produced in a primitive blast-furnace. Fergusson, Vincent Smith, Ganguli and others agree in subscribing to this theory. This theory receives an added

[1] Ibid., 1872, Vol. II, p. 156.

confirmation from the existence of many holes at irregular intervals in the Dhar pillar into which crowbars have evidently been put in order to help welding. Though at first sight the almost perfect finish of the exterior, specially of the Delhi pillar, negatives the hypothesis of forging small pieces into one whole, but when we judge of the almost unsurmountable practical difficulties of forging an *entire* piece of wrought iron as the Delhi or Dhar pillar appears to be, the author, at any rate, cannot but subscribe to the view that the method of forging the Delhi, Dhar, and Mount Abu pillars, as well as the gigantic Orissan beams, is unmistakably the same, viz. the method of welding short pieces into entire pillars and beams.

EXPLANATION OF "CORROSION RESISTANCE" POWER OF INDIAN IRON.

(*a*) *Low manganese with low sulphur and high phosphorus.*

Surprise has not unreasonably been expressed at the fact that the iron pillar at Delhi and other ancient specimens of iron have not rusted in a marked degree. General Cunningham offered a curious explanation of this fact by supposing that the oil of the bodies of the pilgrims who visit the Delhi pillar and embrace it as a mark of merit keeps it immune from rusting, but the learned General does not seem to have explained how the capital of the pillar, which is too high for human embrace, could be preserved in the way it has been preserved. The Delhi pillar is the best preserved of all the pillars. Mr. Graves points out that some of the Konarak beams were so heavily rusted that flakes half a foot square and half an inch thick could be scaled off. Most of them, however, were only superficially rusted and the rusting is mainly due to the beams remaining underground for two or more centuries. The iron clamps found at Bodh-Gaya are also very heavily rusted. The specimens of Singalese iron examined by Sir Robert Hadfield were well preserved, though belonging to the fifth century A.D. Dr. A. S. Cushman[1] is disposed to be philosophically inclined when he says, and says perhaps rightly, that "chemical and physical examinations of such ancient specimens might point the

[1] Ibid., 1812, No. 1, p. 177.

way to practical improvement in our own age, for one criticism that was often passed on modern steels was that their tendency to corrode and disintegrade stood in direct ratio to the rapidity with which they were manufactured .... It seems to be a law of Nature that her materials should respond to the manipulations of the hands of man, and acquire properties that machinery cannot give." Be that as it may, two explanations are possible of this remarkable power of ancient specimens of iron of resisting corrosion—either there was something in the composition of the iron or that the beams were painted, or both. To the author it appears that both the factors have operated in enabling the Indian iron pillars and beams to withstand the corroding influence of wind and rain. In the first place the one point remarkable regarding the composition of the Delhi iron, Singhalese iron and other specimens of ancient iron is that all these specimens of iron are *free from manganese and sulphur and contain a tolerably high percentage of phosphorus.* The author agrees with Dr. Cushman when he suggests that probably "low manganese with low sulphur and high phosphorus would lead to high corrosion resistance" in iron.

Dr. Cushman gives an analysis of an iron nail made in Virginia more than one hundred years ago. It was remarkably well preserved and contained, like old Indian iron, "low manganese with low sulphur and high phosphorus." The analysis was as follows :—

	Per cent.
Sulphur	·013
Manganese	·06
Carbon	·03
Phosphorus	·205
Silicon	·121
Copper	·027
Oxygen	·15

Professor Henri Le Chatelier was also struck by the almost complete absence, both of manganese and of carbon, which always occurred in noteworthy proportions in steels made by melting processes and also by the relatively high percentage of phosphorus. He also suggested that it was perhaps to the concurrence of these

three factors that the exceptional durability of ancient Hindoo irons was to be attributed.[1]

The author, however, is not aware of any experiments undertaken to confirm this theory and would take this opportunity of inviting chemists interested in the question of corrosion of iron to make further experiments on the subject.

(b) *Application of paints on iron beams and pillars.*

Besides the question of the composition of Indian iron the author has a suspicion in his mind that the pillars and beams were originally *painted.* Direct evidence on this point is also forthcoming, as Abul Fazal in the 16th century saw the beams at Puri painted.[2] The peculiar colour of the iron, specially at the top portion of the Delhi pillar, which misled early observers into thinking that the pillar was made of copper or bronze, might have been due to some kind of paint used for painting the pillar. The author has found out two formulæ of such paints used for hardening as well as preserving iron instruments in *Sārangadhar Padhati*, a compendium on miscellaneous subjects of the 14th century by the alchemist Sārangdhar. The first formula is briefly the following: "Grind together *pippali* (piper longum), rock salt and *kushtta* wood (costus speciosus or saussurea Lappa) in cow's urine and cover the iron instrument with the mixture thus obtained. On now heating the instrument in the fire and then quenching in oil the instrument will be of superior quality."[3] The second formula runs thus: "Grind together the five kinds of salt, mustard and honey and after painting the instrument with the mixture heat in the fire until at "yellow heat" its colour becomes blue like that of the throat of a peacock. The instrument would, on quenching in cold water, be quite good."[4] Such an instrument will become extremely hard, so

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1 Journal of the Iron and Steel Institute 1912, p. 180.

2 Ganguli's *Orissa and her Remains*, p. 262.

3 पिप्पलीसैन्धवौ कुष्ठं गोमूत्रेण तु पेषयेत् ।
... ...
अनेन लेपयेच्छस्त्रं लिप्तं चाग्नौ प्रतापयेत् ।
ततो निर्व्वापितं तैले लोहं तत्र विशिष्यते ॥

4 पञ्चभिर्लवणैः पिष्टं मधुसिक्तैः ससर्षपैः ।
एभिः प्रलेपयेच्छस्त्रं लिप्तं चाग्नौ प्रतापयेत् ॥

much so that "it will penetrate through the hardest armour as if through leaves of trees." [1] These two formulæ bring out two facts of importance. In the first place it is known as an undoubted fact that in the 14th century at any rate the Hindus were quite familiar with the process of hardening iron by quenching hot iron either in oil or water, and in the second place iron, at least iron instruments, were painted with a mixture containing salt and other ingredients and then heated in the furnace. The exact chemical action that takes place is difficult to understand. At first chlorides of iron are produced which perhaps on heating decompose, leaving a coating of the oxides of iron. It is possible that the Delhi and other pillars and beams were painted with a similar mixture and then heated in the fire, the process being continued, possibly with alterations, from early times down to the fourteenth century.

Dr. Kumarswami gives a somewhat different formula used for a long time in Ceylon and even now to give a 'blued' colour to iron articles and also to prevent rusting. The formula runs thus: "Take two parts of alum, one part of copperas, two parts of the leaves of *oxalis corniculata* and grind together and allow to stand three days; add the juice of one lime and spread over the iron to be coloured; place carefully in the fire until the right colour is attained." [2] Dr. Kumarswami explains the chemical action by supposing that "apparently the oxalic or other organic acid in the preparation reduces any higher oxide of iron to the ferrous state, and when applied to the steel and heated, slight etching takes place and a probable reduction of part of the sulphate to sulphide of iron. The temperature employed would affect the amount of reduction and oxidation. The blue colour is probably due to the uneven distribution of oxide and sulphide of iron."

Moreover in the *Ayeen Akbari* we find that during the Moghul times iron guns when completed were painted with colour paints, and called 'rangin' (coloured). [3]

शिखिग्रीवानुवर्णाभं तप्तपीतं तथौषधम् ।
ततस्तु विमलं तोयं पाययेच्चक्रमुत्तमम् ॥
[1] येन दुर्भेद्यवर्माणि भेदयेत् तरुपर्णवत् ।

[2] Annanda K. Kumarswami, Mediæval Singhalese Art., p. 200.

[3] Ayeen Akbari, Gladwin's Translation, Vol. I, p. 112.

COMPOUNDS OF IRON.

(a) *Oxides of iron.*

Of the compounds of iron the oxides of iron and the sulphide were artificially prepared and used in the Hindu system of medicine. The chloride of iron was also probably known but seldom used. The Buddhist alchemist Nāgārjuna (second century A.D.) is universally credited as the discoverer of the process of "killing" metals and specially iron. For example Chakrapāni (eleventh century) in describing the process of killing iron says: "I shall now describe the science of iron as promulgated by the sage Nāgārjuna." The author of Rasendra-Chintāmani also does the same.[1]

The first notice of 'killing' iron and other metals (gold, silver, lead, copper and tin) occurs in the *Uttartantra* or supplement of the *Sushruta*, which is said by the commentator Dalhana to have been added by Nāgārjuna, who is also the redactor of Sushruta. In it we find the process called *ayaskriti-bidhi* of iron and other metals in which "thin leaves of iron are to be smeared with the levigated powder of 'the salts' and heated in the fire of the cow-dung cakes and then plunged into a decoction of the myrobalans and assafœtida. This process is to be repeated sixteen times. The leaves are then to be ignited in the fire of the wood of *mimosa catechu* (khadira) and afterwards finely powdered and passed through linen of fine texture. The above process is equally applicable to the roasting of the other metals."[2]

Chakrapāni (eleventh century) gives an elaborate account of Nāgārjuna's process which may be summarised thus: "a bar of iron is to be rubbed with the levigated powder of the following vegetable products among others: the belleric myrobalans, *clitoria ternatea, vitis quadrangularis, boharhaavia diffusa* and *verbesina calend.* It is then strongly heated to the fusing point and plunged

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[1] नागार्ज्जुनो मुनीन्द्रः शशास यल्लोहशास्त्रमतिगहनम्।
तस्यानुस्मृतये वयमेतद्विशदाक्षरैर्ब्रूमः।

[2] तीक्ष्णलोहपत्राणि तनूनि लवणवर्गप्रदिग्धानि गोमयाग्निप्रतप्तानि त्रिफलाशालसारादिकषायेण निर्व्वापयेत् षोड़शवारान् ततः खदिराङ्गारतप्तान्युपशान्ततापानि सूक्ष्मचूर्णानि कारयेत्। ......
एतेन सर्व्वलोहेषु अयस्कृतयो व्याख्याताः। सुश्रुत, चिकित्सितस्थान। Chapter X, 9.

into the decoction of the myrobalans. The iron is then powdered by being beaten with an iron hammer. The powder is then digested in the decoction of the myrobalans and roasted repeatedly in a crucible." *Rasendra-chintamani* (thirteenth century) gives the same account of Nāgārjuna's recipie. *Rasendra-shār-saṃgraha* (fourteenth century) gives an elaborate account of the process of killing iron which is given below. *Kānta* (wrought) iron, being the best of all kinds of iron, has been recommended by all authorities as best suited for the purpose of "killing." Rasendra-shār-saṃgraha writes :—

When the proper kind of iron is selected, it is first finely powdered and then purified (शोधित) by macerating it in a decoction of the "three myrobalans" (त्रिफला). The iron is then again immersed in the same decoction and dried again in the sun. This process is to be repeated seven times. This is called "bhānu-pāka-bidhi" (भानुपाकविधि). The iron is next boiled in decoctions of various substances depending on the nature of the disease for which it is to be used. This process is called "sthāli-pāka-bidhi" (स्थालीपाकविधि). The iron thus treated is now washed in clear water and roasted inside two earthenware concave dishes with their mouths placed on each other and luted with mud. This pair of dishes is then put in a pit of suitable dimensions dug in the earth and heated by means of burning cowdung-cakes. This process is called "puta-pāka-bidhi" (पुटपाकविधि). The iron is then to be roasted ten, hundred or even thousand times, and it is elieved that the greater number of "putas" iron has been subjected to, its medicinal efficacy increases in a corresponding degree. The alternate maceration and heating make the powder very light, and, in fact, the test prescribed by Rasendra-shār-saṃgraha by means of which the proper number of putas is to be judged is the extreme lightness of the powder. "The iron is to be roasted until being finely powdered and thrown on water, it will swim like a duck on account of its lightness." [1]

It would interest readers to learn the methods of preparation

[1] वाजीकर्म्मणि विश्वसः दशादिशतपञ्चकः ।
तावदेव पुटेल्लौहं यावच्चूर्णीकृतं जले ।
निःसारत्वे लघुत्वेन समुत्तरति हंसवत् ॥

of killed iron by modern Aurvedic physicians. As most Aurvedic physicians prepare their own medicines, the method of preparing the same medicine varies considerably. So far as we have been able to collect information, there are three different methods of preparing "lauhas."

(1) Some physicians procure the best kind of iron, heat it in a blacksmith's forge and take the rust formed on the surface of the iron.

(2) Others keep steel immersed in cow's urine for years together and take the rust collected on the surface.

(3) While some are reported to prepare their "lauhas" by repeatedly heating powdered ferrous sulphate (হীরাকষ). Of course the method given in Chakrapāni, Rasendra-shār-saṃgraha and other works is followed by many orthodox physicians. In the methods Nos. (1) and (2) the rusts obtained are purified in the usual way, and then formed into balls with cow's urine or a decoction of the "three myrobalans," dried in the sun and calcined in the pit by means of burning cow-dung cakes in the usual way. The balling, powdering and calcining in an enclosed space are repeated ten, hundred or thousand times.

We collected "lauhas" which have undergone different number of "putas" for analysis. The colour of these samples varied from greyish black and grey to orange-red. It was observed that one "puta lauha" was greatly attracted by a magnet, "lauha" which has been calcined ten times was attracted to a less degree, while a sample of seventy-eight "puta lauha" was very slightly attracted. As regards iron which has been calcined hundred or thousand times, it was not in the least attracted by a magnet.

Qualitative analysis [1] showed the presence of a small quantity of soluble salt mostly potassium phosphate, siliceous matter and iron. There was no carbon (as we expected), nor any aluminium. The "one-puta," "ten-puta" and "seventy-eight-puta" "lauhas" are the products of heating the same sample of iron. The "hundred-puta" and "thousand-puta" "lauhas," both marked (A), are again the oxidation products of another sample

[1] The process of "killing" iron and analysis of "killed" iron have been reproduced here from a paper by the author and Mr. Birendra Bhusan Adhicari, Journal of the Asiatic Society of Bengal, 1910, 385.

of iron. Lastly, the "thousand-puta" "lauha," marked (B), is a different preparation.

"One-puta lauha."

Fe =(5 c.c. H. only)	=	·012
Feo	=	68·1
Fe_2o_3	=	20·4
Siliceous matter	=	10·1
Soluble salt (mostly pot. phos.)	=	1·3
		99·912

"Ten-puta lauha."

Fe	=	nil.
Feo	=	23·1
Fe_2o_3	=	40·0
Siliceous matter	=	32·1
Soluble salt	=	4·6
		99·8 mm.

"Seventy-eight puta lauha."

Fe	=	nil.
Feo	=	9·5
Fe_2o_3	=	51·2
Siliceous matter	=	34·1
Soluble salt	=	5·4
		100·2

"Hundred-puta lauha." (*A*)

Fe	=	nil.
Feo	=	nil.
Fe_2o_3	=	83·9
Siliceous matter	=	12·7
Soluble salt (of which P_2o_5=·9)	=	3·7
		100·3

"Thousand-puta lauha." (A)

Fe	=	nil.
Feo	=	nil.
Fe_2o_3	=	78·1
Siliceous matter	=	17·9
Soluble salt	=	4·1
		100·1

"Thousand-puta lauha." (B)

Fe	=	nil.
Feo	=	nil.
Fe_2o_3	=	84·9
Siliceous matter	=	11·3
Soluble salt (of which P_2o_5=1·2)	=	3·8
		99·7

From the results of analysis given above it is clear that the magnetic properties of the samples of iron which have undergone a fewer number of "putas" are not due to free iron, which is present in minute quantities in the "one-puta" "lauha" but to

ferroso-ferric oxides, the ferrous and ferric oxides being present in them in varying proportions.[1]

As the number of "putas" increases, the amount of ferrous oxide diminishes, and at hundred "putas," and above, the iron is wholly present in the form of ferric oxide. Hence "hundred-puta" and "thousand-puta" "lauhas" are not attracted by the magnet.

2. Siliceous matter is present in very large proportion varying from 10·1 to as much as 34·1 per cent. This impurity comes, as was subsequently ascertained, from the stone plates (शिला) on which the iron is powdered many times.

3. "Shata-puta," "Sahasra-puta," "lauhas" have almost identical composition. Both are impure ferric oxide, the percentage of which varies from 78·1 to 84·6. Both are non-magnetic and "swim like duck" on water. On account of the very large number of "putas" in the course of which it undergoes maceration, powdering and roasting for a thousand times, the "shahasra puta" "lauha" is lighter and finer than "shata-puta." The time taken to prepare these lauhas is very long indeed. If one "puta" be finished in one day, the preparation of "shata-puta" takes more than three months, and that of "shahasra-puta" about three years. As the roasting is carried on in closed vessels the oxidation proceeds very slowly. If, however, open vessels be employed in future the time may be greatly curtailed.

4. The test of "swimming on water like a duck" is a crucial one with the Aurvedic physician for "lauhas." We have seen that precipitated ferric oxide of the laboratory does not "swim like a duck." It is probable that Aurvedic "lauhas," being very light and porous, are easily assimilated in the body while ordinary ferric oxide being not so light and porous is not easily taken up and hence not used by Allopathic doctors.

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1 Of Roscoe and Schorlemmer's "Treatise on Chemistry," Vol. II, Part 2, "Magnetic oxide of iron";—"when iron is heated to redness in the air, it becomes coated with iron scale. This is a mixture or a compound of the monoxide and sesquioxide in varying proportions. The inner layer which is blackish grey, porous, brittle, and attracted by the magnet, has the composition 6 Feo Fe_2o_3 and is not magnetic. The outer layer contains a larger quantity of ferric oxide, is of a reddish colour and is more strongly attracted by the magnet than the inner portion."

SULPHIDE OF IRON.

The sulphide of iron does not seem to have been prepared in the pure state. It occurs in preparations such as *lauha-parpati*, *sidha-jogeswar* and other Tantrik medicines along with the sulphide of mercury and vegetable substances. The mixture of sulphides (lauha-parpati) is prepared, as described in Rasendra-shār-samgraha and other works, by taking two parts of mercury, two parts of sulphur and one part of killed iron and then melting this well-rubbed powder in an iron laddle with clarified butter on a gentle fire. It is then poured over plantain leaves and gently pressed and finally treated with vegetable substances.

CHLORIDES OF IRON.

We have already referred to the *ayaskriti* of iron mentioned in the *Uttartantra* of the Shushruta in which iron is heated with the "salts" including common salt. A mixture of ferrous chloride and oxychloride and oxide of iron is probably formed in this reaction. The five kinds of salts are sauvarchala (probably nitre), saindhaba (rock salt), vit (a kind of common salt), audbhida (alkali carbonate) and sāmudra (sea-salt).

CHAPTER V.

METALLURGY OF INDIAN IRON.

ORES AND MINES OF IRON IN ANCIENT INDIA.

From the enormous deposits of iron slag and cinder in many parts of India it is evident that iron was extensively manufactured from its ores in various places throughout India. The ores of iron described in the Arthashāstra of Kautilya, as mentioned before, are evidently hæmatites. Hæmatites were known in Hindu medico-chemical literature as *gairik,* and the bright red variety or red hæmatite was called *subarna gairik* (golden gairik).[1] Gairik is mentioned in the Amarkosha. It was also used as a dye for dyeing clothes. Iron pyrites was known in Aurvedic literature as *tāpya* or *rauppa-mākhika* (silver pyrites). Two varieties of *tāpya* are mentioned in Charaka and Sushruta (third century B.C.) and latterly copper and iron pyrites were designated as *swarna-mākhika* (golden pyrites) and *rauppa-mākhika.*

In the Ayeen Akbari we find that during Akbar's time there were iron mines in Bajuha, subah Bengal, in Keroh, subah Kashmir, and in Kumāun within the Delhi subah, also at Nirmul and Indore to the north of Golconda where excellent iron and steel were obtained. Tavernier in his "Travels" mentions that there were gold, silver, steel, lead and iron mines in Assam[2] and that iron manufactured at Haidrabad was pure.[3] Manucci wrote that iron was abundant in Golconda which was principally celebrated for diamond mines. The *Dhātukriyā*. a work of the sixteenth century mentions that iron ores were plentiful in Lohādri, Gayādri, Gautamādri, Vindya Hills, Nạlādri, Trymbaka and seaside places. It must be understood that these references are merely casual and they do not give any systematic information regarding the existence of iron mines in ancient India

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[1] सुवर्णगैरिकम् तु अन्यस्तो रक्ततरं हि तत्। भावप्रकाश।

[2] Tavernier's "Travels in India," Vol. II, pp. 281, 284.

[3] Tavernier, *ibid.*, Vol. I, p. 157.

"DIRECT" PROCESS OF MANUFACTURING WROUGHT IRON.

The ancient method of manufacturing iron still prevails in various parts of the country, notably in Orissa, Chota Nagpur, Central Provinces, Baroda, the Deccan and Carnatic, and North-Western Provinces. It has mainly passed into the hands of ignorant and in many places aboriginal tribes, but it is certain that in early times the Delhi and the Dhar pillars and the Orissan beams must have been forged by skilled metallurgists (लोहशास्त्रवित्) and engineers. Any one who studies the growth and decay of the intellectual and scientific activities of the Hindoos will see clearly that scientific industries were declining from a long time, and owing to a lack of initiative the old processes struggled on on a continuously diminutive scale until almost all industries passed into the hands of the least advanced sections of the Hindu community. It has already been stated that the iron beams of the temples in Orissa, which was famous for her iron in all ages, may have been prepared from iron manufactured in the Talchir districts where iron-smelting is still carried on by the Kols. Mr. H. F. Blandford of the Geological Survey of India says, "The iron smelters of Talchir and neighbouring districts belong to the large tribe of Cols . . . lumps of slag are frequently found in jungly districts where no iron manufacture has been carried on within the memory of the inhabitants." The author also guesses that the iron of the Delhi and Mount Abu pillars was probably obtained from Rajputana, as large hillocks of iron-slag are found in Khetri and other places in Rajputana, which is now being utilised as a flux by the native copper smelters. The iron of the Dhar pillar evidently has come from Southern India which was famous, until recently, for iron and steel

It is a matter for regret that Sanskrit literature, as far as is known to the author, contains little or no information regarding the actual method of the manufacture of iron or the furnaces employed in smelting the ores or in forging iron, though we can easily conceive that the furnaces, which forged the Delhi and other pillars even piece by piece, must have been of great dimensions. There existed undoubtedly *lohasāstras* or "sciences of iron (or metals)", the author of one of which was Patanjali, who flourished in the second century B.C. and was the commentator of the celebrated grammarian Pānini. These unfortunately have all perished. Ball speaks only

what is half true when he says, " The rude smelting-furnaces of the natives . . . are probably to a great extent the lineal descendants of a system of iron manufacture, which, in the earliest times of which we have any record, must have been on a scale of considerable magnitude."[1] We may, however, readily admit that the principle followed in the existing indigenous method of manufacturing iron was probably the same in ancient times, though iron must have been produced in India on a very large scale and in much bigger furnaces by intelligent Hindu workers.

Fortunately we have got accounts of the manufacture of iron in India left by Dr. Buchanan who visited India in 1800, and by Heyne whose " Tracts on India" was published in 1814 embodying the results of his observations from 1794. In the accounts of these travellers we find descriptions of the process of manufacturing iron as it existed more than a hundred years ago. The process described in these books as well as that which exists even now may be called the "*direct process*" of manufacturing wrought iron or malleable iron—a process which does not require the previous preparation of cast-iron. The modern European process of making wrought iron may be called the "indirect process" in which wrought iron is obtained by the almost total removal of carbon from cast iron which is first directly obtained from the ores. This direct process of manufacturing wrought iron, which has existed in India from very ancient times, is still carried on not only in India but also in "Borneo and Africa; nor indeed is it yet extinct in Europe: it is stated, moreover, to be still extensively employed in Vermont and New Jersy, U.S."[2] We may safely conclude that the iron of the Delhi and Dhar pillars and of the Orissan beams was prepared from iron ores by this *direct process*.

The *rationale* of the process is as follows:—Only the richest ores of iron are employed, and the fuel as well as the reducing agent is charcoal. The blast furnace consists of a hearth with a circular shaft or chimney from 2 to 6 feet high and 2 to 3 feet broad, and the blast is admitted with a hand-bellows through a hole. As charcoal is a much purer form of carbon than coal the iron pro-

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1 Ball's "Geology of India," Part III, p. 340.

2 Percy's "Metallurgy," Vol. II, p. 254.

duced by heating the ores with charcoal is exceedingly pure. No flux seems to have been used as only pure ores were employed, though Dr. Verchere testifies that in Wariristan a flux of limestone is added even at the present day. The malleable iron thus obtained directly from the ores is hammered in the hot condition in order to make the iron solid and homogeneous. The iron slag during the process of heating is tapped off from time to time through another hole or tuyere, and the adhering portion of it is squeezed out during the hammering. The iron seems to have been obtained as lumps and not in the molten condition.

Heyne in his "Tracts" gives an account of iron manufacture as he saw in the Northern Circars which he visited in 1794, also at Yeragutty near Satgur and at Ramanakapetta near Nuzid.[1] At the first place the ores employed were a kind of iron-stone having the appearance of yellow and brown ochre. At the second place the ores were a kind of "fine black sand found in small rivulets or nullahs that derive their source from the neighbouring mountains" —a "sub-species of micaceous iron ore" very rich in iron and attracted powerfully by the magnet. In the third place the ores used were hæmatites.

Heyne gives a drawing of an iron-furnace used at Yeragutty which is reproduced here. "The furnaces are made of red loam mixed with sand and consists of two parts. The lower and larger is about three spaces high and a foot in diameter; quite cylindrical, and erected over a hole in the ground, about four inches deep; its sides are everywhere about two inches thick. The upper part is conical, with the higher portion of the cone reversed. It is about eighteen inches high, and at the opening not quite a foot in diameter. The bellows are of a kind used by the iron smiths, and made of sheep's skin: a hole is left near the bottom of the cylindrical part of the furnace to receive their nozzle." When smelting iron the two parts of the furnace are cemented with some loam and the bottom is filled with charcoal which is then ignited. One part of ore and four parts of charcoal are added at a time at the interval of about fifteen minutes, and the bellows are worked. This produces sufficient heat, if not to melt the iron, at least to

[1] Heyne's "Tracts on India," pp. 189, 218, 224.

PLATE X

Iron Furnace.

(Heyne's Tracts on India, 1814, page [illegible].)

soften it, and at the end of the operation the iron is found in a solid mass at the bottom of the furnace which is put a second time into the fire and subjected to the action of the hammer.

At the Northern Circars and at Ramanakapetta the furnaces, described by Heyne, are bigger in size and semicircular in shape "very much resembling in shape the half a hen's egg divided longitudinally with the largest end uppermost." The wall is built of clay and the height 4½ feet and breadth 3 feet 9 inches. The external and convex surface has one of its sides, at the bottom, an excavation serving to receive the slag which is let out through a hole in the bottom. The mode of the construction of the inner part of the furnace is somewhat different. The ore and charcoal are used in the proportion of one to two. The iron obtained is also in the solid condition.

Buchanan who visited Southern India in 1800 saw in Malabar iron manufacture from black iron sand in which the greater part of the Malabar Hills abounds. He also saw the same method of manufacturing iron from black iron sand on his way from Serangapatam to Bangalore and from both stone-ore and sand-ore in the districts of Madhugiri, Chin-nārāyan-durga, Hagalawadi, and Devaraya-durga. The methods and furnaces used are much the same as described by Heyne, the iron being obtained in the solid condition showing that the heat in the furnaces was sufficient only for softening the metal.[1] The reason for the comparative lowness of the temperature is the want of powerful bellows.

Dr. Percy in his "Metallurgy" gives an elaborate description of the furnaces used and processes employed from the reports of the Geological Survey of India, from which we can learn how iron was manufactured in the middle of the nineteeth century as Percy's work was published in 1864. He writes: "The ores employed are magnetic oxide and rich red and brown hæmatites. Captain Campbell states he has seen specular iron ore used by the Konds of Goomsoor. The process of smelting varies somewhat in different districts; and this variation is due partly to local custom and

[1] For details the reader is referred to Buchanan's "Travels from Madras through Mysore, Canara and Malabar," Vol. I, pp. 118 and 306, Vol. II, 118, in which sketches and sections of the furnaces used in making iron and steel are given.

partly to the fact that the art has most advanced where the population is most dense and civilized. The furnaces may be divided into three typical kinds. The first kind is employed on the west coast of India, in the Western Ghats and usually through the Deccan and Carnatic and is the rudest form of furnace in use in the less civilized districts and among the Hill tribes. The *second* and *third* are employed in Central India and the North-Western Provinces and resemble the simplest forms of the Catalan forge and the German Stückofen respectively: they are greatly in advance of the first and are capable of producing wrought-iron in considerable quantity as well as natural steel." (For details and diagrams consult the book).[1]

WHY WROUGHT IRON AND NOT CAST IRON IS PRODUCED BY THE INDIAN PROCESS.

It will be seen that the iron produced in the first place by the Indian method is always wrought iron and not cast-iron which is produced as the first product in modern blast furnaces. The reason is not far to seek. It will appear from the accounts of manufacture given above that the temperature in the furnaces is only sufficient to soften the iron so that small particles might agglutinate to each other but not sufficient to melt it, while the temperature at the hottest zone of a modern blast furnace is 1400° or more. The result is that in a modern blast furnace the iron begins to take up carbon at 1000° and becomes saturated with the latter as it descends to the zone in which the temperature is 1400°, thus becoming converted into cast iron. It must however be admitted that at the lower temperature of the Indian furnaces a large portion of the iron ores escapes reduction to metallic iron.

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[1] Percy's Metallurgy, Vol. II, p. 253 *et seq.*

CHAPTER VI.

INDIAN STEEL OR WOOTZ.

DERIVATION OF "WOOTZ."

The word "wootz," by which name Indian steel was and is still known in Europe, is a curious word meaning steel made in Southern India. The name seems to have originated in some clerical error or misreading very possibly for "*wook*" representing the Canarese word "*ukku*" meaning steel, and first appears in a paper read by George Pearson, M.D., before the Royal Society of England in June 11, 1795, and entitled "experiments and observations to investigate the nature of a kind of steel manufactured at Bombay and there called *wootz*."[1] Mr. J. M. Heath is evidently wrong in thinking "wootz" to be the name for steel in the Guzerattee language in use at Bombay. Dr. Edward Bulfour suggested that the word "wootz" perhaps was "uchcha," meaning "of superior quality," in the Canarese language, as distinguished from "nicha" or "of inferior quality." This suggestion does not appear to be satisfactory at all.

HISTORICAL.

Wootz seems to have been prepared from time immemorial in the Nizam's Dominions, Mysore and Salem, and other parts of the Madras Presidency and was the metal from which the famous Damascus blades were prepared. The presence of numerous Asoka pillars of stone cut out in a faultless manner from single pieces of stone of gigantic dimensions presupposes the use of the finest steel saws and steel chisels in India in the fourth century B.C. The use of a large number of surgical instruments in the Sushruta (third century B.C.), some of which "could bisect a hair longitudinally," also points out to the use of steel in India in making cutlery and

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1 Hobson-Jobson, "Glossary," p. 972.

surgical instruments in pre-Christian times. Moreover "we can hardly doubt that the tools with which the Egyptians covered their obelisks and temples of porphyry and syenite with hieroglyphics were made of Indian steel. There is no evidence to show that any of the nations of antiquity besides the Hindus were acquainted with the art of making steel. The notices which occur in the Greek and Latin writers on this subject serve only to betray their ignorance of it; they were acquainted with the qualities and familiar with the use of steel, but they appear to have been altogether ignorant of the mode in which it was prepared from iron. The arms and cutting instruments of the ancients were all formed of alloys of copper and tin, and we are certain that tools of such an alloy could not have been employed in sculpturing porphyry and syenite .... One certain fact has reached us regarding the antiquity of the steel manufacture in India: Quintus Curtius mentions that a present of steel was made to Alexander of Macedon by Porus, an Indian Chief, whose country he had invaded. We can hardly believe that a matter of about thirty pounds' weight of steel would have been considered a present worthy of the acceptance of the conqueror of the world, had the manufacture of that substance been practised by any of the nations of the West in the days of Alexander....... We know that a maritime intercourse was maintained from the remotest antiquity between the Malabar Coast, the Persian Gulf, the country about the mouths of the Indus and the Red Sea; and it appears reasonable to conclude that the steel of the south of India found its way by these routes to the country of Porus, to the nations of Europe and to Egypt."[1]

Abundant evidence is forthcoming to testify to the fact that India supplied the iron for the famous Damascus blades. Sir George Birdwood says, "Indian steel was celebrated from the earliest antiquity, and the blades of Damascus which maintained their pre-eminence even after the blades of Toledo became celebrated, were in fact of Indian iron. Ctasias mentions two wonderful Indian blades which were presented to him by the King of Persia and his mother. The Ondanique of Marco Polo's travels refers originally, as Col. Yule has shown, to Indian steel, the word being

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[1] J. M. Heath, Journal Royal Asiatic Society, 1839, Vol. V, 395.

a corruption of the Persian Hundwaniy, i.e. Indian steel: The same word found its way into Spanish in the shape of "Al-hinde" and "Al-finde" first with the meaning of steel and then of a steel mirror and finally of the metal foil of a glass mirror. The Ondanique of Kirman, which Marco Polo mentions, was so called from its comparative excellence, and the swords of Kirman were eagerly sought after in the fifteenth and sixteenth centuries A.D. by the Turks who gave great prices for them. Arrian mentions steel as imported into the Abyssinian ports, and Salmasius mentions that among the surviving Greek treatises was one on the tempering of Indian steel."[1] The celebrated traveller Tavernier writing about Indian iron of his time said, "The steel susceptible of being damasked comes from the Kingdom of Golconda; it is met with in commerce in lumps about the size of a half-penny cake; they are cut in two, in order to see whether they are of good quality, and each makes half the blade of a sabre." Even in the early part of the nineteenth century the trade in steel with Persia was quite profitable. Dr. Voysey in his article on the "Description of the Native Manufacture of Steel in Southern India"[2] writes: "The export, however, of the metal to Persia must be profitable, as it is sufficient to bring dealers from that country and to defray the cost and risk of travelling. We found at the village (named 'Kona Samundram,' 12 miles south of the Godaveri and 25 miles from Nirmul, celebrated for its manufacture of steel), in 1820, Haji Hosyn, from Ispahan, engaged in the speculation; and it must have answered his purpose, as he was here again in 1823, having returned in the interval to Persia and disposed of the venture. He informed us that the place and the process are both familiar to the Persians and that they have attempted to imitate the latter without success." Syed Hussain Bilgrami[3] writes, "From time immemorial the iron of the Nizam's territories has been worked at Yalgharab, Nirmul, Juctial, Warangal and other places into blooms

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[1] Sir George Birdwood's "Hand-book to the British Indian Section of the Paris Exhibition of 1878."

[2] An extract from the manuscript journals of Dr. Voysey printed in Journal Asiatic Society (of Bengal), Vol. I, 1832, p. 247.

[3] Syed Hossain Bilgrami on "Iron Industry in Hyderabad," Journal of the Iron and Steel Institute, 1899, No. 11, p. 75.

from which cast steel of a very superior quality was manufactured and exported to the far West. It has been proved that the raw material from which the famous Damascus blade was manufactured, was obtained from an obscure village in the Nizam's territory" (meaning perhaps the village of Kona Samundram described above by Dr. Voysey). The geologist Ball holds the same opinion and writes in his "Geology of India" that "there are distinct evidences that wootz was exported to the West in very early times, possibly 2000 years ago."

It would interest readers to learn in what parts of India itself, which supplied the steel for making Damascus blades, swords were manufactured. We find a list of such places in *Yuktikalpataru*, which has already been referred to as a manuscript of the eleventh century, which says that swords were manufactured in Benares, Magadha, Ceylon, Nepal, Anga, Mysore, Surat and Orissa (Kalinga) and describes the qualities of the swords manufactured in the various places.[1] We have found a similar reference in *Shārangadhar-Padhati*, a work undoubtedly composed in the fourteenth century by the alchemist Shārangadhar. In it we find that in the fourteenth century the following places were noted for the manufacture of swords, viz. Khatikhattara, Rishi, Banga (Bengal), Shurporaka, Videha (Mithilā or Tirhut), Anga (Bhāgulpur), Madyamā-grām, Bedidesha, Sahagrām, and Kalinjar, and that swords manufactured

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[1] तद्यथा वाराणसीमगधसिंहलभूमिभागे नेपालभूमिषु तथाङ्गमहीप्रदेशे ।
सौराष्ट्रिकेऽन्यतरधन्यमहीविभागे खड्गायसां जातवरां प्रवदन्ति जन्म तद्‌ यथा ॥
वाराणसेयाः सुस्निग्धास्तीक्ष्णधाराः सदङ्गिणः ।
लघवः सुखसन्धेयाः छेदोत्साभिवशालिनः ।
मागधाः कर्कशाः स्थूलधारामूलतरङ्गिणः ।
गुरवो दुःखसन्धेया वज्राङ्गेया विचक्षणैः ।
नैपालदेशप्रभवाः निरङ्गाः निश्चलाश्च ये ।
वङ्गाः सदङ्गामलिनाः लघवः स्थूलधारिणः ।
कलिङ्गाः गुरवः स्वच्छाश्चन्द्राशाखिन्दुभेदवः ।
सौराष्ट्राः निर्मलाः स्निग्धाः सुखसन्धानभङ्गुराः ।
सिंहलद्वीपजातानां चतुर्भेद उच्यते ।
केचित् सदङ्गा गुरवः कर्कशास्तीक्ष्णधारिणः ।
केचित् सदङ्गालघवः सस्निग्धास्थूलधारिणः । युक्तिकल्पतरु ।

in China were "faultless and pure." [1] In *Shārangadhar Padhati* as well as in *Yuktikalpataru* long chapters on the dimensions and qualities of swords as well as on varieties of iron and their different colours have been inserted.

The Sanskrit equivalent for steel is *tikshna.* The word occurs in the *Arthasāstra* (p. 83) and in the *Sushruta* (see *ayaskriti*), but it is doubtful if the word meant any particular *kind* of iron in those ancient times. In the *Rasaratna-samucchaya* six varieties of *tikshna* iron are mentioned (see p. 45). In the Bhābaprakāsha (sixteenth century) steel is called *shār-lauha,* and is described as a "kind of iron which when treated with acid becomes as sharp as the peak of a mountain."

MANUFACTURE OF WOOTZ—CRUCIBLE PROCESS OF MAKING CAST-STEEL BY CEMENTATION.

We would now proceed to describe the traditional Indian method of manufacturing steel—"the ondanique of Marco Polo—which supplied many a true blade girded by Asiatic conquerors of yore, and may be said to have overthrown dynasties and established empires." It has already been said that Indian steel was in great demand in the Middle Ages not only in Asia but also in Europe, and many attempts at imitation were naturally made by Europeans though uusuccessfully. Mr. Henry Wilkinson informs us in this connection that "with respect to the various

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[1] खटि-खट्टर-रौषिक-वंग-शूर्पारकेषु च ।
विदेहेषु तथाङ्गेषु मध्यमग्राम वेदिषु ।
सहग्रामेषु चीनेषु तथा कालञ्जरेषु च ।
लोहप्रधानं तद्ज्ञानं खड्गानां शृणु लक्षणं ।
खटीखट्टरजाता ये दर्शनीयास्तु ते मताः ।
कायच्छिदः स्वार्षिकार्यै सर्व्वसंग्रामुरवस्तथा ।
तीक्ष्णाः छेदसहाः वङ्गाः दृढाः शूर्पारकोद्भवाः ।
अखण्डाश्चैव विज्ञेयाः प्रभावन्तो विदेहजाः ।
अङ्गदेशोद्भवास्तीक्ष्णाः मध्यमग्रामसम्भवाः ।
अधाराश्च घनास्तीक्ष्णाः वेदिदेशसमुद्भवाः ।
सहग्रामोद्भवाः खड्गाः सुतीक्ष्णाश्च घनास्तथा ।
निर्मलाश्चिन्नसंलास्तीक्ष्णाश्चीनदेशसमुद्भवाः ।
कालिञ्जराः कालमहास्तेषां वक्ष्यामि लक्षणं ।
इत्यत् शार्ङ्गधरपद्धति, खड्गप्रशंसा ।

attempts at imitation, the least ingenious one is certainly that of etching or engraving a blade of common steel, more to deceive the purchaser. Amongst the numerous failures we may enumerate those of Messrs. Nicholson, O'Reilly, Wilde and others in England as well as that of Monsieur Clouet in France.'' [1]

The first to examine wootz chemically was Dr. Pearson, who in 1795 contributed a paper on the subject to the Philosophical Transactions of the Royal Society (Part II). The difference between wrought iron and steel, as is well known, lies in the fact that steel contains more carbon than wrought iron while cast iron contains still more carbon than either wrought iron or steel. But owing to the imperfect methods of analysis prevalent at that time Dr. Pearson states the results of his analysis of the percentage of carbon in a curious fashion. He estimated '' the quantity of carbon in the wootz and steel to be nearly equal; and that quantity to be about one-third of the hundredth part or $\frac{1}{300}$ of the weight of these substances.'' He also estimated the specific gravity of wootz as follows:—

1.	Wootz	7·181
2.	Another specimen of wootz ..	7·403
3.	The same forged	7·647
4.	Another specimen forged .	7·503
5.	Wootz which had been melted ..	7·200
6.	Wootz which had been quenched while white hot..	7·166

Dr. Scott who forwarded the specimens of wootz to Dr. Pearson from Bombay described that wootz was used '' for cutting iron on a lathe, for cutting stones, for chisels, for making files, for saws, and for every purpose where excessive hardness was necessary.'' Wootz, however, could not bear anything beyond a very slight red heat, which made it work very tediously in the hands of smiths. There is very little of chemical importance in Dr. Pearson's paper, and he was quite mistaken, as will be shown below, in thinking '' we may without risk conclude that it (wootz) is made directly from the ore and consequently that it has never been in the state of wrought iron,'' the actual process being

[1] Journal Royal Asiatic Society, 1837, Vol. IV, p. 188.

just the reverse, viz. carburisation of wrought iron. Faraday and Stoddart had also examined wootz.

The first complete analysis of 'wootz' was made by Mr. T. H. Henry in the middle of the ninteenth century. The results of his analysis are given below:—

Carbon combined	..	1·333	1·340
,, uncombined	..	·312	..
Silicon ..	..	·045	·042
Sulphur ..	.	·181	·170
Arsenic ..	..	·037	·036
Iron by difference	..	98·092	
		100·000	

Steel may be prepared in two ways, firstly, by removing part of the carbon of cast iron before it is converted into wrought iron; or secondly, by carburising wrought iron or making it combine with the requisite quantity of carbon. The second process is called the "process of cementation" and has been discovered in England only in the eighteenth century, while Indian iron was prepared by this process from time immemorial. As has already been mentioned, Sir Robert Hadfield on examining photomicrographically some ancient Ceylonese iron specimens of the fifth century A.D. found that a chisel showed distinct signs of carburisation varying on the two faces "from saturation point (·9 per cent) to about ·2 per cent carbon on the outside edge." He further remarks: "the presence of martensite and hardenite suggests the important information that the chisel has been quenched."[1] Sir Robert concludes: "the author believes this to be the first time there has been put up on record evidence of the art of cementation having been known 1500 to 2000 years ago, as shown by these specimens; probably therefore, such knowledge could be traced back still further." Ceylon, having been only a part of Greater India, we may safely conclude that the process of cementation and quenching was known in India "1500 to 2000 years ago," if not earlier.

[1] Journal of Iron and Steel Institute, 1912, Vol. 85, No 1, p. 164.

Judging from the conservatism of the people we would expect to find the same process in working in the eighteenth or nineteenth century, though it must be confessed, on an infinitely smaller scale, as the scientific spirit of enquiry and industrial enterprise seem to have almost left India to find a new habitat in Europe at the close of the seventeenth century. We have, however, got excellent account of steel manufacture in Southern India from the accounts of travellers like Dr. Voysey (1795), Buchanan (1800) and Heyne (1794-1814). The process of Indian steel-making may be summarised in the following way—wrought iron is first obtained by the *direct method*, viz. heating the ores of iron with charcoal in small blast furnaces (the blast being admitted by means of hand bellows) without the intermediate formation of cast iron as has already been described. The wrought iron is then cut into small pieces and taken in crucibles along with certain kinds of wood and leaves of plants and then heated in charcoal blast furnaces with the lids closed. The blast is continued from four to six hours when the steel is obtained in the molten condition. Water is then sprinkled or poured on the metal, which is thus hardened on being quenched and the steel obtained in a crystalline condition.

We give below Heyne's account of steel-making in Mysore which was published in 1814.[1] "In order to convert the iron into steel each piece is cut into three parts, making fifty-two in the whole, each of which is put into a crucible, together with a handful of the dried branches of "tangedu" (cassia auriculata) and another of fresh leaves of "vonangady" (convolvulus laurifolia). The mouth of the crucible is then closely shut with a handful of red mud, and the whole arranged in circular order with their bottoms turned towards the centre in a hole made on the ground for the purpose. The whole is then filled up with charcoal, and large bellows are kept blowing for six hours, by which time the operation is finished. The crucibles are then removed from the furnace, ranged in rows on moistened mud, and water is thrown on them whilst yet hot. The steel is found in conical pieces at the bottom of the crucibles, the form of which it has taken. The upper or broader surface is often striated from

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[1] Heyne's "Tracts on India, historical and statistical," p. 359.

the centre to the circumference. The iron ore used is magnetic iron sand common all over the coast and even found on the sea-beach near Madras." The steel thus obtained is heated again in closed crucibles so that the excess of carbon is burnt out. Dr. Heyne also publishes a letter from Mr. Stoddart that even up to his time, not to speak of Indian steel of the Middle Ages, " Indian steel was decidedly superior to any other description of steel."

The well-known traveller Dr. Buchanan who visited Southern India in 1800 also gives a similar account of steel-making.[1] " In each is put one-third part of a wedge of iron, with three rupees' weight of the stem of " tayngada " or cassia auriculata and two green leaves of the " hugivany " which is no doubt a convolvulus or an Ipomea with a large smooth leaf; but never having seen the flower, I could not in such a difficult class of plants attempt to ascertain the species. The mouth of the crucible is then covered with a round cap of unbaked clay and the junction is well luted." The crucibles are then dried and heated in a charcoal furnace fed with hand-bellows. The operation is conducted in four hours. When the crucibles are opened, the steel is found melted into a bottom with evident marks on its superior surface of a tendency to crystallization, which shows clearly that it has undergone a complete fusion. The steel is subjected to heat a second time in closed crucibles until the metal is obtained in a suitable condition.

Syed Hossain Bilgrami in his lecture on " Iron industry in the Hyderabad and Deccan " before the Iron and Steel Institute has given a similar narrative of the crucible process of steel-making in the Nizam's Dominions, the wood used " being a species of cassia, very common in the country and known as *cassia tora* and the leaves those of calatropis gigantea." [2]

A similar method of manufacturing cast-steel was prevalent in Ceylon from early times, though the native method of steel-making has almost been beaten out of the country by foreign competition. Mr. Ananda K. Kumarswamy writes in his Mediæval Singhalese Art: " the steel is made in clay crucibles, each about eight

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[1] Buchanan's " Travels from Madras through Mysore, &c.", p. 308.

[2] Syed Hossain Bilgrami: Journal of Iron and Steel Institute, 1899, Vol. II, p. 75.

inches long, two inches in diameter, and a quarter of an inch in thickness. In the crucible is put a piece of iron, with some chips of *cassia auriculata*, in the proportion of 12½ oz. iron to 5 oz. wood, in the case examined. The crucible is covered with a lid, having small holes pierced for the escape of gas; six crucibles thus prepared are embedded in the charcoal and a fire started. Very soon the woods burn off, and while this goes on the blowing is stopped. Then the blast is kept up continuously." The steel obtained in the course of a few hours is highly crystalline.

CRUCIBLE PROCESS OF MAKING CAST-STEEL—AN INDIAN DISCOVERY.

From the accounts given above it is evident that the traditional Indian method of making steel was the crucible process of making cast-steel in a fused condition by cementation, which process should in reality be regarded as an Indian discovery. The chemical action that takes places, as suggested by Heath, is that during the application of heat to the closed crucible the dry wood and green leaves would yield charcoal as well as an abundant supply of hydrocarbons. The *joint action of carbon and hydrocarbons* on the iron greatly facilitates the formation of steel as the European method of cementation by means of *charcoal alone* used to take six or seven *days*, and even fourteen to twenty *days*, while the Indian process takes only four to six *hours*. Though cementation has been mentioned by Agricola in his *de re metallica*, and though Reaumer in 1722 described the process of converting bar-iron into "blistered steel," it was only in 1800 that Mr. D. Mushet took out a patent for converting malleable iron into *cast-steel* by fusing it in a closed crucible in contact with carbon. "Now this specification," says Mr. Heath, "unquestionably comprises the principle of the Indian process which adopts the use of dry wood, which is a substance containing the coaly or carbonaceous principle." This opinion is confirmed by Dr. Percy who says, "It is curious that Mushet's process, so far as relates to the use of malleable iron in the production of cast-steel, should in principle, and I may add even in practice too, be identical with that by which the Hindoos have from ancient times prepared their wootz. I cannot discover any essential difference between

the two."[1] Dr. Percy, however, did not take into consideration the action of carburetted hydrogen gas produced by the destructive decomposition of wood in the Indian process, though as a matter of fact in the year 1825 Mr. Charles Mackintosh actually took out a patent for converting malleable iron into steel by exposing it to the action of carburetted hydrogen gas in a closed vessel, at a very high temperature, by which means the process of conversion into steel is completed in a few hours while by the old method it was the work of from fourteen to twenty days.

As regards the particular kind of wood employed, the selection of *cassia auriculata* (from which catechu is obtained) and of the leaf of *convolvulus* may not be altogether an accident. It is possible that experience had taught the Indian workers the use of these two kinds of wood as affording suitable quantities of carbon and hydrocarbons to the iron so that the conversion of iron into steel could take place more quickly than with other kinds of wood.

As regards the proportion of carbon contained in steel, the excess of carbon is burnt away during reheating. In this connection the remarks of Ritter Cecil von Schwarz, who was for some time in charge of the Bengal Iron Works Company, would be interesting. He wrote: "It is well known by every manufacturer of crucible cast-steel how difficult it is sometimes to get the exact degree of hardness to suit certain purposes, especially with reference to steel for cutting the blades, etc. With the ordinary process endeavours are made to reach the required degree of hardness by selecting such raw materials as on an average have the required contents of carbon in order to correspond with the required degree of hardness as far as possible. The natives (of India) reached this degree by introducing into their cast-steel an excess of carbon, by taking this excess gradually away afterwards, by means of the slow tempering process, having it thus completely in their power to attain the exact degree by interrupting this decarbonising process exactly at the proper time in order to cast steel of a quality exactly suitable for the purpose."[2]

We hope we have been able to give a trustworthy account of

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1 Percy's "Metallurgy," Vol. II, p. 778.

2 Quoted in P. C. Ray's History of Hindu Chemistry, Vol. I.

the process of the manufacture of Indian steel, which was an object of envy of all nations but successfully imitated by none and which supplied the materials of many a true blade of warriors both in the East and the West. It is sad to reflect that an ancient indigenous industry which attracted merchants from Persia, as narrated by Dr. Voysey, barely hundred years ago, is on the point of extinction; but as even the darkest cloud is not without a silver lining, a distinct ray of hope is visible in the not very distant horizon presaging that India will yet regain her lost iron industry under modern scientific conditions together with other attendant industries depending upon iron.

CHAPTER VII.

CAST IRON.

That cast iron was known in ancient India is undoubted. It has already been pointed out that three distinct varieties of iron, viz. "munda," "tikshna" and "kānta," meaning respectively cast iron, steel and wrought iron, are mentioned in the Tantrik works of the thirteenth or fourteenth century such as *Rasaratna-samucchaya* and *Rasendra-shār-saṃgraha*. We would draw prominent attention to the description of three varieties of "munda" iron in the *Rasaratna-samucchaya* which are undoubtedly varieties of cast iron, "that which *easily melts*, does not break and is glossy is *mridu*; that which expands *with difficulty* when struck with a hammer is known as *kuntha*; that which *breaks* when struck with a hammer and has a black fracture is kadāra."

It is, however, undoubted that wrought iron and steel were mainly produced in India, and as Lester[1] says, "Cast iron was produced in India only by accident." Cast iron guns were cast in England in 1543 while in India such guns appear to have been cast in the eighteenth century, these being very probably introduced into India from Europe. It has already been pointed out that during the manufacture of cast iron, pure iron takes up carbon at about 1000°—1400°, which temperature was very seldom attained in the Indian furnaces owing to insufficient blast.

Cast iron rusts much more quickly than wrought iron and ancient specimens cannot well be looked for unless large blocks of such iron should remain buried. A remarkable block of such iron has a few years ago been unearthed by the Rungpur Shāhitya Parishad in the ruins of Bhabachandra-pāt, the old capital of king Bhabachandra, near Rungpur. The block with fragments weighed about one and a half maund (about 120 lbs). A sample was sent to the author for examination. Though its exterior was rusted,

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[1] "Iron and Coal Trades Review," Vol. LXXXIII, 561.

its interior when freshly broken was bright and crystalline. It broke at the first stroke of the hammer and when the bright powder was kept for several days only it was heavily rusted. When the metal was dissolved in dilute acid a quantity of black carbon remained behind and the issuing hydrogen had the foetid smell characteristic of cast iron. The result of analysis of a sample is given below:—

Iron	96·42 per cent.
Total carbon	2·81 ,, ,,
Manganese	·21 ,, ,,
	99·44

This specimen of cast iron is unique so far as India is concerned, as specimens of wrought iron alone are abundant in India. No exact date can be assigned to King Bhabachandra. His name has passed current in Bengali fable as a foolish king having a foolish minister named Habachandra. The ruins of Bhabachandra-pāt are very old and it is supposed that it was the capital of a dynasty of Hindu kings before the Mahomedan conquest. The specimen may be dated from the eighth to the tenth century A.D.

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